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[ETD 15: Rotating Machinery]

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बिजली की मशीनरी के लिये ब्रुश सामग्री – विशिष्टि

Indian Standard

BRUSH MATERIALS FOR ELECTRICAL MACHINERY — SPECIFICATION

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BUREAU OF INDIAN STANDARDS
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FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Rotating Machinery Sectional Committee had been approved by the Electrotechnical Division Council.

(Continued on third cover)

Indian Standard

BRUSH MATERIALS FOR ELECTRICAL MACHINERY — SPECIFICATION

1 SCOPE

1.1 This standard covers the test methods and the tolerances applicable for determination of the properties which are inherent in the brush materials for electrical machinery.

1.2 The performance characteristics of the carbon brushes in operation on electrical equipment will be covered later.

2 REFERENCE STANDARDS

The Indian Standards listed in Annex A are necessary adjuncts to this standard.

3 TERMINOLOGY

For the purpose of this standard, the definitions given in IS 13586 : 1992 shall apply.

4 TOLERANCES

4.1 Values of physical properties published is catalogues of the manufacturers of brush material shall be based upon test methods given in this standard and shall be subject to the tolerances specified in Table 1. It may be noted that the values of tolerances specified are the maximum values and those may be reduced suitably for a particular application, if considered necessary and agreed to between the user and the supplier.

Table 1 Tolerances

(*Clauses* 4.1, 6.2.5, 7.4, 8.4, 9.4, 10.4 *and* 11.3.3)

Characteristics	Tolerance on Declared Values
Density	Not exceeding ± 5 percent
Porosity	Under consideration
Hardness	Not exceeding ± 15 percent
Resistivity	Not exceeding ± 25 percent
Transverse strength	Not exceeding ± 20 percent
Ash content	*See* Note in 10.4 and Fig. 6
Brush wear	*See* Note in 11.3.3

5 TEST SPECIMEN

5.1 Some of the properties are to be determined on a standard test specimen (sample) with dimensions as given in **8.2**. When the test specimen is cut from brush block material, it is necessary (in order to obtain a correct value when measuring the hardness and the transverse strength) that the thickness *p*, width *w* and length *l* (*see* Fig. 1 and 2) have a definite relation to the direction of pressing pressure or axis of extrusion. The length *L* shall be perpendicular to the direction of compression for pressed blocks and shall be along the axis of extrusion for extruded blocks. On brush material of laminated structure, the thickness *p* shall be perpendicular to the lamination (parallel to the direction of compression).

5.2 The dimensions $p \times w \times l$ of the standard test specimen should be:

10 mm × 10 mm × 64 mm

or

4 mm × 8 mm × 32 mm

NOTE — *See* **5.4** for tolerance on dimensions.

5.2.1 Where practicable, a test specimen may be cut from a manufactured brush provided it meets the requirements of **4.1** and for which a cutting plan may be obtained from the carbon brush manufacturers.

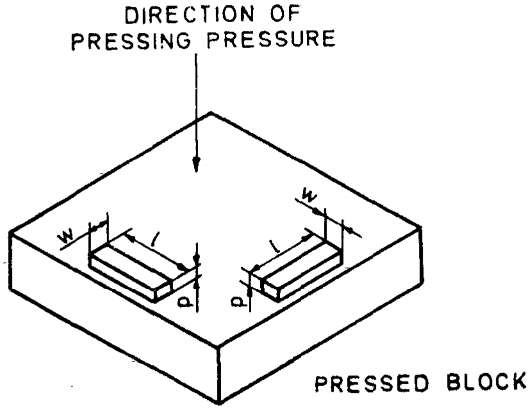


FIG. 1 RELATION BETWEEN DIMENSIONS *p*, *w* AND *l* OF TEST SPECIMEN AND DIRECTION OF PRESSING PRESSURE

5.2.2 In cases where it is not possible to cut a standard size test specimen from a manufactured brush, the size should be a matter of agreement between the user and the supplier. Caution should be used in testing smaller size pieces as the deviation may be great, due to difficulty in handling.

5.3 All adjacent surfaces shall be at right angles. The specimen should be carefully machined to the surface finish normally used for carbon brushes. All traces of any die skin or extrusion skin should be removed.

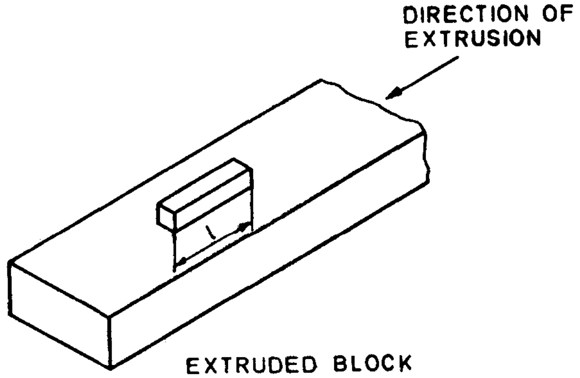


FIG. 2 RELATION BETWEEN DIMENSIONS p, w AND l OF TEST SPECIMEN AND DIRECTION OF EXTRUSION

5.4 The tolerance on the dimensions p and w is ±0.04 mm and the tolerance on the dimension s is ±0.8 mm.

When a large number of test specimens are concerned and density is one of the properties measured, it is more convenient to apply the tolerance of ± 0.04 mm to dimension l is well as to dimensions p and w.

In order to ensure squareness of $p \times w$ section, the tolerance for the angles shall be ±15. The parallelism defined by the difference between the dimensions of the two opposite sides at any cross section perpendicular to the dimension l should be within 0.04 mm.

6 DENSITY AND POROSITY

6.1 Letter Symbols

The following letter symbols are used for quantities:

m = mass of test specimen (dry), in g;

V_b = bulk (apparent) volume of material (including accessible and closed pores), in cm^3;

V_o = volume of the accessible pores of the specimen, in cm^3;

δ_b = bulk density, in g/cm^3;

P_s = apparent porosity, in percentage; and

d = diameter, in mm.

The bulk density is then defined by the equation:

$$\delta_b = \frac{m}{V_b}$$

The apparent porosity is defined by the formula:

$$P_s = \frac{V_o}{V_b} \times 100 \text{ percent}$$

6.2 Methods for Determining the Bulk Density and Porosity

The bulk density may be determined by one of following standard methods:

a) Measurements-and-weight method (**6.2.2**),

b) Immersion method (**6.2.3**), and

c) Oil-absorption method (**6.2.4**).

The porosity P_s may be determined by the oil-absorption method.

6.2.1 The measurements-and-weight method is suitable for production quality control and should preferably be used. The immersion method is considered to be an alternative and may be used in cases where the measurements-and-weight method cannot be applied or is unsuitable. The oil-absorption method is suitable for laboratory use. All these methods are considered accurate to three significant figures, which is sufficiently accurate for checking these properties.

NOTE — The oil-absorption method may give unreliable values for material with a porosity higher than 30 percent.

6.2.2 *Measurements-and-Weight Method*

6.2.2.1 *Equipment and test specimen*

The following shall be required:

a) Micrometer with an accuracy of ±0.01 mm suitable for measuring the test specimen;

b) A scale of single fan balance to determined mass (m) in grams. The sensitivity of measurement shall be 0.5 percent or better. The balance of capacity 100 g and sensitivity ±0.005 g may be found suitable for normal samples;

c) Saw or other device for cutting the sample to a required size;

d) Grinding wheel or other device for machining the test specimen so that all adjacent surfaces are at right angles; and

e) The specimen in accordance with **5.4** or any rectangular or cylindrical sample of a suitable size the ends of which are plane at an right angles to the sides.

6.2.2.2 *Procedure*

The measurements necessary for calculating the volume of the test sample shall be made using the micrometer. This requires measuring the thickness, width and length of rectangular pieces or the diameter and length of cylindrical pieces. These measurements shall be taken to the nearest hundredth of a millimetre.

The sample shall be weighed in grams to three significant decimal places.

6.2.2.3 *Calculations*

The volume V_b of the sample expressed in cm^3 shall be calculated as follows:

$$V_b = p \times w \times l \quad \text{for rectangular pieces}$$

or

$$= \frac{\pi d^2}{4} \times l \quad \text{for cylindrical pieces}$$

The bulk density δ_b shall be calculated as follows:

$$\delta_b = \frac{m}{V_b}$$

6.2.3 *Immersion Method*

6.2.3.1 *Equipment and test specimen*

The following shall be required:

a) Container of water large enough to immerse the test sample;

b) Weighing scale or balance in accordance with **6.2.2.1**(b);

c) Grease or other waterproof masking material for coating the sample to prevent the absorption of water;

d) Thread to suspend sample while it is being weighed during immersion. The diameter of the thread shall not exceed 0.08 mm; and

e) Test specimen.

As this method may be used for irregularly-shaped samples, no preparation is necessary beyond making sure that the sample is clean, dry and free from extraneous metal or foreign material.

6.2.3.2 *Procedure*

The sample shall be weighed in air. All surface of the sample shall be coated as thinly as possible with grease or other waterproof masking material. The sample shall be weighed in air again. The increase due to the coating should not exceed one part in 200. The result shall be expressed in grams to three significant figures.

The sample shall be suspended by a piece of thread from the balance. It shall be immersed completely in water, taking care to remove all air bubbles, and it shall be weighed while it is thus immersed. The minimum possible length of thread shall be used.

6.2.3.3 *Calculations*

When weighed in air, the force on the sample (due to gravity) is G_a, when the sample is immersed in water, the force on it (due to gravity) is also G_a, but, according to Archimedes' principle another force $\gamma_w \times V_b$ (where γ_w is the specific gravity of water and V_b is the volume of the sample) is also acting on the sample so that the weight measured in water is:

$$G_l = G_a - \gamma_w V_b$$

However,

$$V_b = \frac{m}{\delta_b} = \frac{G_a}{g \cdot \delta_b}$$

and $\quad \gamma_w = g \times \delta_w$

where g is the acceleration due to gravity and γ_w is the density of the water.

Thus: $$G_l = G_a - \frac{\delta_w \times G_a}{\delta_b}$$

or

$$\delta_b (G_a - G_l) = \delta_w \times G_a$$

or

$$\delta_b = \delta_w \times \frac{G_a}{G_a - G_l}$$

The value of δ_w is very close to *l*.

6.2.4 *Oil-Absorption Method*

6.2.4.1 *Equipment and test specimen*

The following shall be required:

a) A weighing scale or balance in accordance with **6.2.2.1**(b);

b) Hydrometer having a specific gravity range of 0.800 to 0.900 at 20°C and graduated to 0.001;

c) Hydrometer cylinder;

d) Thermometer having a range of −10°C to +100°C, accuracy 0.1°C;

e) Banker of wide mouth and a capacity of 1 000 cm^3;

f) Vacuum desiccator or bell jar;

g) Vacuum pump capable of developing an absolute pressure of 20 mm Hg (about 25 mbar);

h) Water-bath maintained at a temperature below 20°C;

j) Petroleum oil grade SAE-10 (24-32 CSt at 50°C) or kerosene;

k) Saw or other device for cutting the sample to a required size;

m) Grinding wheel or other device for smoothing off rough edges; and

n) A test specimen with a mass of 25 to 100 g. If the sample is taken from a piece which originally had metal fittings, plating, etc, all such foreign material shall be removed. All surfaces shall be ground to reasonable smoothness so that there are no burrs or sharp edges to chip off during the test. In general, metal-graphite grades and very dense materials should be tested in samples larger than those taken from other brush materials.

6.2.4.2 *Procedure*

The sample shall be weighed in air to three significant figures.

The sample and a thermometer shall be placed in the beaker and the pump connected to the beaker. The pressure shall be reduced gradually to 20 to 60 mm Hg (about 25-80 mbar).

Without breaking the vacuum preheated to 70°C, the oil or kerosene shall be gradually introduced into the beaker so that the sample is covered completely with oil.

The pressure shall be maintained at 20 to 60 mm Hg (about 25-80 mbar) for 5 hours or until the sample stops emitting bubbles, whichever is reached earlier.

NOTE — To judge that sample has stopped emitting bubbles, it would be seen that no bubble is evolved during a period of half an hour.

The beaker and its contents shall be cooled to below 20°C in the waterbath. The beaker shall be removed from the bath and the temperature shall be allowed to rise to 20°C.

At this point, the sample shall be removed from the oil and wiped dry.

The oil-impregnated sample shall be weighed in air to three significant figures. This mass G_2, shall be recorded.

The oil from the beaker shall be pured into the hydrometer cylinder, bring its temperature up to 20°C and its specific gravity shall be read. This value shall be recorded as δ_O.

The oil-impregnated sample submerged in water shall be weighed as described in **6.2.3.2**. This mass, G_3, shall be recorded.

6.2.4.3 *Calculation*

The mass of the oil-absorbed is $G_O = G_2 - G_a$. Thus the volume of oil-absorbed is $V_O = \frac{G_O}{\delta_O}$. In analogy with the calculations in **6.2.3.2**, the bulk density *b* can be obtained as:

$$\delta_b = \delta_w \times \frac{G_a}{G_2 - G_3}$$

and the porosity

$$P_s = \frac{V_o}{V_b} \times 100 \text{ percent}$$

6.2.5 The values of bulk density as obtained from any of the test method specified in **6.2.2** to **6.2.4** shall comply with the declared value subject to a tolerance given in Table 1.

6.2.6 The value of porosity as obtained from **6.2.4** shall comply with value declared by the manufacturer. The tolerance on porosity is under consideration. If required, the tolerance shall be a subject of agreement between the user and the manufacturer.

7 HARDNESS

7.1 General

There are two methods in general use for determining the hardness of brush materials, namely:

a) Rebound method (**7.2**), and

b) Indentation method (**7.3**).

7.1.1 It should be kept in mind that there is no general relation between the hardness of a brush material and the abrasiveness of the same material.

7.1.2 It is recognized that results obtained for a particular test method can be checked only against results obtained by the same method and standardized against equivalent standards. The rebound method of hardness measurement reflects the property of elasticity of material whereas the indentation method indicates the plasticity of material. The user may specify the method to be used for determining the hardness of brush material. In case method (b) is being followed shore hardness value shall also be indicated by the manufacturer.

7.1.3 The value of hardness measured on individual brushes may not be comparable to those taken on other brushes, or on brush blocks, unless the direction of pressing or of extrusion is the same.

7.2 Rebound Method

This test method is suitable for production, quality control, especially if the material to be tested is not very soft.

7.2.1 *Equipment and Test Specimen*

The following shall be required:

a) Scleroscope, Shore model C[2] or equivalent, equipped with a special hammer for testing brush material.

NOTE — The hammer and its components should be as follows:

i)	Mass	: 2.2 g ± 5 percent;
ii)	Outside diameter	: $5.94^{+0.013}_{-0}$ mm;
iii)	Overall length	: 20.7 to 21.4 mm;
iv)	Clearance between hammer and tube —	
	at the top of tube	: 0.19 to 0.31 mm;
	at the bottom of the tube	: 0.04 to 0.08 mm;
v)	Height from which and hammer falls	: $251.21^{+0.13}_{-0.38}$ mm;

vi) The tip of the hammer should be a diamond, oval in shape and driven into a tapered hole in the hammer body. The body should be of water hardening drill-rod containing approximately 1.2 percent of carbon and should be hardened and tempered after insertion of the diamond. Measured at the contact surface, the diamond should have a curvature of 1.32 mm ±5 percent, measured over a 0.61 mm long arc.

b) The test specimen may be of a size indicated in **5.2** or any other convenient size. The piece to be tested should have the skin removed, and the surface should be machined smooth and free from defects, dirt, grit or other foreign material. A rectangular piece should have at least two parallel surfaces. A circular piece should have a uniform diameter, otherwise the hammer will strike the piece a glancing blow and false readings will result. Preferably, and if permissible, when testing circular pieces two parallel flat surfaces should be machined to facilitate accurate testing.

7.2.2 *Setting-Up the Instrument*

The instruments shall be placed on a firm support and levelled up.

It shall be checked that the 'plumb bob' on the front of the instrument can swing freely in the ring.

The calibration of the instrument shall be checked using previously prepared reference samples.

The anvil for the test piece shall be prepared.

If the test piece is circular in cross section and suitable parallel flat surfaces cannot be machined, the vee-block anvil shall be used. If the test piece is rectangular in cross section, the basic flat anvil (which is part of the instrument proper) shall be used.

NOTE — Keep the anvils clean. Wipe dust and dirt particles off the anvil with a soft lintless cloth. When a vee-block anvil is used, wipe the flat anvil and the mating surface of the vee-block anvil, clean before placing them together. Dirt particles between the two anvils would cause false readings.

7.2.3 *Procedure*

The piece shall be placed on the appropriate anvil so that the hammer impact is applied in the direction of the pressing pressure in the case of brush block materials and perpendicular to the axis of extrusion for extruded materials.

The tube shall be lowered against the test piece and held firmly while the test is being made.

The hammer shall be released and the height of the rebound shall be read.

If possible, the hardness shall be measured at five points on each side of the test specimen.

To avoid random low readings giving a false result, the lowest readings in each of the two groups of five readings shall be disregarded. The average of the eight remaining readings is taken as being representative of the hardness of the specimen.

7.3 Indentation Method

The test consists in forcing a ball into the surface of a test piece in two operations and measuring the permanent increase of the depth of indentation of this ball under specified conditions (*see* Fig. 3).

The hardness may be measured directly on manufactured brushes if:

a) the brush is not coppered and t, a and r [*see* Doc : ETDC 15(3100)] are at least 10 mm; or

b) the brush is coppered and a to t are at least 10 mm and at the same time the part of r that is not coppered is at least 10 mm.

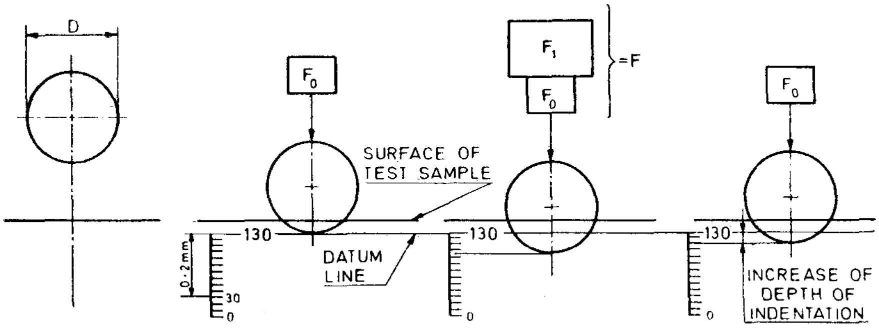
Measurements taken on a smaller specimen may be subject to error due to possible effects of cracking, crushing and deformation.

For all other brushes, the measurement of the hardness should be made on the brush block material before the brushes are cut to size.

7.3.1 *Equipment and Test Specimen*

The following shall be required:

a) Rockwell hardness test apparatus (Ponetrometer) with equipment for different loads F_0, F_1 and F (*see* Fig. 3). A device (such as a dashpot) should be incorporated to prevent the load from being applied suddenly, it should be adjusted so that, during the hardness test, the load increases from F_0 to $F = F_0 + F_1$ within 2 to 8 second;



D = Diameter of ball penetrator
F_0 = Preliminary load
F_1 = Additional load

FIG. 3 HARDNESS TEST : INDENTATION METHOD

b) Ball indenter made of polished material and having a diameter of D mm. No diameter of the ball should differ from the nominal diameter by more than the value corresponding to grade *j*6 as given in IS 919 (Part 1) : 1963. The ball should have a Vickers hardness of at least 850 (taking into account the curvature of the ball, when testing); it should be polished and free from surface defects. Any ball showing any deformation after the test greater than the tolerance specified above, or any surface defect, should be rejected and the corresponding test discarded;

c) Indicator (depth gauge) for measuring the permanent increase of depth of indentation. The indicator is to have a uniform dial scale reading from 0 to 130 where the distance between the scale division 30 and 130 should correspond to a depth of indentation of 0.200 mm that is one scale unit corresponds to 0.002 mm. The indicator should be accurate to ± 0.001 mm; and

d) Rigid support for the test piece. Test specimen shall be in accordance with **5.2** or any sample of a suitable size with two parallel surfaces. Before the hardness test, the sample should be inspected to ensure that there are no cracks or other surface defects. The surface in contact with the support and the surface to be tested should be clean and free from foreign matter. When a hardness test is made on brush block material, it should be checked that the two parallel surface are carefully machined to the surface finish normally used for carbon brushes.

NOTE — After each change or removal and replacement of the ball penetrator or the support, it should be ascertained that the new penetrator (or the new support) is correctly mounted in its housing. Throughout the test, the apparatus should be protected from shock or vibration.

7.3.2 *Test Procedure*

The test shall be carried out at ambient temperature. It is important that the sample lies firmly on the support of that displacement cannot occur during the test. Unless otherwise agreed, the sample should be placed so that the direction of the load during the hardness test will be applied in the direction of pressing pressure in the case of brush block materials and perpendicular to the axis of extrusion for extruded materials.

The position of any indentation shall be chosen in such a way that the distance between the centres of two adjacent indentations or from the centre of any indentation to the edge of the sample or to any cavity will be at least one ball diameter or 2.5 times the diameter of the impression diameter, unless otherwise agreed to between the user and the supplier.

A combination of a ball diameter D, preliminary load F_0 and additional load F_1 shall be chosen as follows:

Combination 1	:	for natural graphite materials;
Combination 2	:	for metal graphite materials;
Combinations 3, 4 and 5	:	for metal graphite, electrographite and hard carbon materials.

	Combinations Number					*Unit*
	1	(2)[1]	3	4	5	
D	10	(10)[1]	10	10	10	mm
F_0	10	(10)[1]	10	10	10	kgf
F_1	10	(30)[1]	50	90	140	kgf
$F = F_0 + F_1$	20	(40)[1]	60	100	150	kgf

[1] These combinations should be avoided as far as possible.

NOTE — In accordance with the practice laid down by the International Organization for Standardization (ISO), the loads for all hardness testing are expressed in kgf. This decision was taken as it is considered impracticable to change the loads on all standard hardness testing machine to daN.

Where none of the listed combinations gives a suitable reading, a different size ball may be used, and this information included in the report. In this situation, preference should be given to using a 5 mm diameter ball, with the combinations of lead given above.

The ball shall be placed against the surface of the test piece. Pressure shall be applied gradually to the ball perpendicular to the surface without sudden shock until the preliminary load F_0 of l_0 + 0.2 kgf is attained.

The dial of the indicator (depth gauge) shall be set at the initial position.

The load shall be increased without sudden shock and within 2 to 8 seconds, by the value of additional load F_1, thus obtaining a total load $F = F_0 + F_1$. The tolerance on F_1 is ± 0.5 percent.

When the needle of the indicator (depth gauge) is steady, which generally takes up to 10 seconds according to the material being tested, the additional load F_1 shall be removed so as to bring the load back to the preliminary load F_0.

In special cases, where the brush material under these conditions of the test, shows greater time dependant plasticity, F_1 shall be removed 20 to 25 seconds after the indicator commences to move.

The permanent increase of depth of indentation shall be read from the dial while the preliminary load F_0 is still applied. Deduce, if necessary, the corresponding Rockwell hardness number (most dial scales give a direct reading of the Rockwell hardness number of the red scale). If, when using one combination of the table, the average value obtained is greater than 110 or less than 50, the test should be repeated using a more suitable combination.

The following number of hardness tests on each sample shall be made:

a) On manufactured brushes where the two dimensions of the surface to be tested are both less than 16 mm: 1 test on each of the two surfaces;

b) On manufactured brushes where the two dimensions of the surface to be tested are both at least 16 mm: 2 tests on each of the two surfaces; and

c) On brush block material: 5 tests on each of the two surfaces.

The arithmetical mean value of the readings taken on each sample shall be recorded as the hardness. However, in the case of brush block material it is advisable to disregard the lowest value obtained on each face; the arithmetical mean of the eight remaining results is then considered representative of the hardness.

The hardness value obtained for a specified load should be designated by the letters *HR* in combination with an index figure stating which ball diameter *D* and total load *F* had been used, for instance *HR* 10/60.

7.4 The value of hardness obtained in accordance with any of the test methods specified in **7.2** and **7.3** shall comply with the declared value subject to a tolerance given in Table 1.

8 RESISTIVITY

8.1 General

There are several different methods in general use for determining the resistivity of brush materials. The methods used most frequently for production quality control are the following:

a) Voltmeter-ammeter method (**8.2**), and

b) Kelvin bridge method (**8.3**).

8.2 Voltmeter-Ammeter Method

8.2.1 *Equipment and Test Specimen*

The following shall be required:

a) Source of direct current providing a range of 0 to 6 volts and 40 A, for example, storage battery and variable resistance;

b) Millivoltmeter for direct current having a resistance of at least 1 000 Ω/V and preferably having the following scales:

0 to 300 mV
0 to 150 mV
0 to 75 mV
0 to 30 mV
0 to 15 mV
0 to 7.5 mV
0 to 3 mV;

c) Ammeter for direct current preferably having the following scales:

0 to 75 A
0 to 30 A
0 to 15 A
0 to 7.5 A
0 to 3 A;

(All instruments shall have accuracy not inferior to class 1.5 of IS 1248 (Part 1) : 1983);

d) Switch for breaking and closing the test circuit;

e) Two current contacts comprising resilient (for instance copper gauge) or self-aligning contact surfaces. The two surfaces are to be suitably arranged to hold between them a standard test specimen of dimensions given in **5.2**;

f) Sharp potential pointers of stainless steel having a spacing not less than 30 percent and not greater than 50 percent of the length of the specimen. The tolerance on the spacing is ±1 percent of its nominal value; and

g) Test specimen in accordance with **5.2**.

8.2.2 *Procedure*

The test specimen should be tested at room temperature.

The dimensions of the test specimen shall be measured and recorded to an accuracy of 0.5 percent or better.

The test specimen shall be placed length-wise between the two current impinging contacts.

The potential pointers shall be pressed against one of the surfaces $w \times d$ of the specimen. The force on the potential pointers is considered to be sufficient if the needle of the millivoltmeter is steady.

It shall be checked that the potential pointers are symmetrically located in relation to the axis of the surface $w \times l$.

The potential pointer spacing shall be recorded.

NOTE — This potential pointer spacing should be checked at regular intervals. The check is made by pressing the pointers against a flat ground surface of a piece of brush material on which clear, well defined marks are easily obtained. The distance between the centres of these marks l_u is then measured by means of a microscope (*see* Fig.4).

The current shall be passed through the test circuit. Suitable scale on ammeter and millivoltmeter shall be chosen and the value of the current adjusted, by means of the variable resistance, so that readings of over 50 percent full scale deflect are obtained on both instruments.

NOTES

1 Suggested values of current, potential pointer spacing and millivoltmeter scale are given in Table 2.

2 The readings should be taken quickly in order to avoid heating the specimen since this may influence the value of the resistivity.

The ammeter and millivoltmeter readings shall be recorded and the electric current through the test circuit shall be broken.

The potential pointers shall be disengaged from the surface of the test specimen.

The pressure from the two current contacts shall be removed, the test specimen turned over, so that the potential pointers are in contact with the other surface $w \times l$ and the same force as before shall be applied.

The test procedure shall be repeated using the same current.

The arithmetical mean value of the voltage drops measured on the two surfaces $w \times l$ is used for calculation of the resistivity.

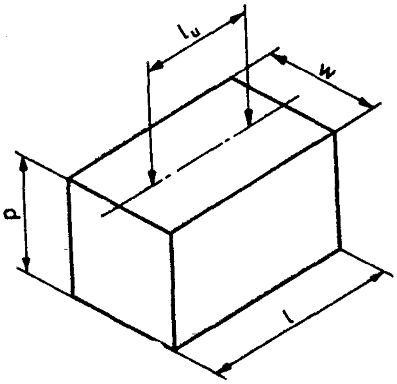


FIG. 4 TEST SAMPLE FOR RESISTIVITY MEASUREMENT

8.2.3 *Calculations*

The resistivity (specific resistance) ρ is calculated in accordance with the following formula:

$$\rho = \frac{U \times p \times w}{I \times l_u}$$

where

ρ = resistivity (specific resistance) of the brush material in ohmmetres;

U = voltage drop between the potential pointers in volts;

p = thickness of test specimen in metres;

w = width of test specimen in metres;

I = current through test specimen in amperes; and

l_u = distance between the potential pointers in metres.

NOTE — It is recommended that the resistivity of brush materials should be quoted in microohm-metre units (μΩ m). ρ is obtained in microohm-metre if, in the formula above, U is measured in millivolts, I in amperes and p, w and l_u all in millimetres.

8.3 Kelvin Bridge Method

8.3.1 *Equipment and Test Specimen*

The following shall be required:

a) Source of direct current, ammeter, resilient (for instance copper gauge) or self-aligning current contacts and potential pointers in accordance with **8.2.1**;

b) Kelvin bridge having a range of 10 microohms to 1 ohm;

c) Galvanometer sensitive to 1 microampere per scale division;

d) Switch for passing the current intermittently through the specimen; and

e) Test specimen in accordance with **5.2**.

Table 2 Preferred Values of Specimen and Testing Conditions

(*Clause* 8.2.2)

Test Specimen $p \times w \times l$	l_u	ρ_{Max}	I	U_{Max}
(1)	(2)	(3)	(4)	(5)
mm × mm × mm	mm	μΩ m	A	mV
10 × 10 × 64	25	600.00	2.00	300.0
		200.00	4.00	300.0
		150.00	8.00	300.0
		75.00	8.00	150.0
		37.50	8.00	75.0
		15.00	8.00	30.0
		7.50	8.00	15.0
		3.75	8.00	7.5
		1.50	20.00	7.5
		0.75	40.00	7.5
		0.60	20.00	3.0
		0.30	40.00	3.0
4 × 8 × 32	16	600.00	1.00	300.0
		300.00	2.00	300.0
		150.00	4.00	300.0
		75.00	4.00	150.0
		37.50	4.00	75.0
		15.00	4.00	30.0
		7.50	4.00	15.0
		3.75	4.00	7.5
		1.50	10.00	7.5
		0.75	20.00	7.5
		0.60	10.00	3.0
		0.30	20.00	3.0

8.3.2 *Test Procedure*

The specimen should be tested at room temperature.

The dimensions of the test specimen shall be measured and recorded to an accuracy of 0.5 percent or better.

The test specimen shall be placed lengthwise between the two current contacts.

The test specimen shall be connected to the Kelvin bridge correctly and carefully.

The potential pointers shall be pressed against one of the surface $w \times l$ of the specimen. The force on the potential pointers is considered to be sufficient if the needle of the millivoltmeter is steady.

The potential pointers shall be checked to ensure that these are symmetrically located in relation to the axis of the surface $w \times l$.

The potential pointer spacing shall be recorded.

NOTE — The adjustment of the bridge resistance should be made as quickly as possible in order to avoid any heating of the specimen that may influence the value of the resistance.

The potential pointers shall be disengaged from the surface of the test specimen.

The pressure from the two current contacts shall be removed, the test specimen turned over, so that the potential pointers are in contact with the other surface $w \times l$ of the specimen, and the same force shall be applied as before.

The test procedure shall be repeated using the same current.

The arithmetical mean value of the resistances measured on the two surfaces $w \times l$ is used for calculation of the resistivity.

8.3.3 *Calculation*

The resistivity is calculated as follows:

$$\rho = \frac{R \times p \times w}{l_u}$$

where

ρ = resistivity (specific resistance) of the brush material in ohm-metres;

R = resistance of test specimen, between potential pointers, in ohms;

P = thickness of test specimen in metres;

w = width of test specimen in metre; and

l_u = distance between potential pointers, in metres.

NOTE — ρ is obtained in microohm-metres if, in the formula above, R is measured in milliohms and p, w and l_u in millimetres.

It is recommended that the resistivity of brush materials should be quoted in microohm metre units (μΩ m).

8.4 The value of the resistivity obtained in accordance with any of the test methods specified in **8.2** and **8.3** shall comply with the declared value subject to a tolerance given in Table 1.

9 TRANSVERSE STRENGTH

9.1 Equipment and Test Specimen

The following shall be required:

a) Pressure device with a suitable pressure gauge or scale; for example, any hydraulic or mechanical press. The device should be capable of developing and measuring force up to about 1 500 N with an accuracy of ±2 percent;

b) Three knife edges:

The radius for the loading knife edge should be 4 to 5 mm; and

The radius for the supporting knife edges should be 1 mm ± 0.5 mm.

The outer two knife edges (the supporting knife edges) should lie in the same plane and be parallel and the distance between their centres should not differ from the nominal value by more than ± 0.2 mm. The knife edge in the middle, the loading knife edge should always be parallel to the two outer ones and should be movable in a plane perpendicular to the plane through the two supporting knife edges and located midway between them (*see* Fig. 5).

c) The test specimen should be in accordance with **5.2**.

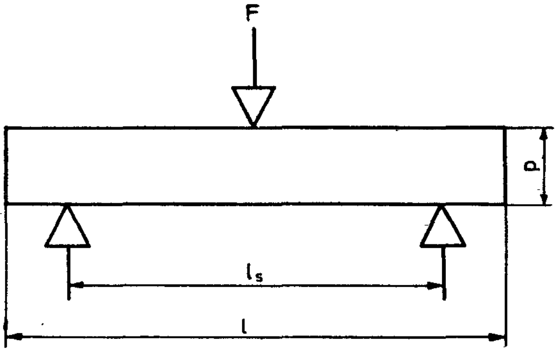


FIG. 5 THREE KNIFE EDGES FOR TRANSVERSE STRENGTH

9.2 Test Procedure

It shall be checked that the distance *l* between the two supporting knife edges is equal to the value recommended in Table 3. Record the distance l_s.

The dimensions of the test specimen shall be checked and recorded. *w* and *p* should be measured to an accuracy of 0.5 percent or better.

The specimen shall be placed symmetrically on the two supporting knife edges with the dimensions *l* perpendicular to the knife edges and the dimension *w* parallel to them.

The stress at the centre of the specimen shall be applied by means of the leading knife edge, midway between the two supporting knife edges.

NOTES

1 The loading knife edge should be able to move in its vertical plane and parallel to the supporting knife edges without causing any measurable parasitic friction.

2 The force should be applied at a uniform rate without shock so that the rupture taken place is not less than 5 seconds.

The total net force *F* at which the test specimen ruptures shall be recorded.

9.3 Calculations

The transverse strength θ is calculated as follows:

$$\theta = \frac{3}{2} \times \frac{l_s}{w.p^2} \times F$$

where

θ = transverse strength of the brush material in MN/m^2,

F = total not force at the instant of rupture in N,

l_s = distance between supporting knife edges in mm,

w = width of test specimen in mm, and

p = thickness of test specimen in mm.

Table 3 gives, for each of the two standard test specimens, the recommended value for l_s and the corresponding value for the co-efficient '*C*' :

$$\text{'}C\text{'} = \frac{3}{2} \times \frac{l_s}{w.p^2}$$

θ in MN/m^2 is then simply obtained from the formula:

$$\theta = c \times F$$

Table 3 Recommended Spacing (l_s) for Test Loads

(*Clauses* 9.2 *and* 9.3)

Dimension of Standard Test Specimen			Recommended Value of	Corresponding Values of *c*
p	*w*	*l*	l_s	1
mm	mm	mm	mm	mm^2
10	10	64	50.0	0.075
4	8	32	25.6	0.300

9.3.1 Whenever possible, test specimens of 10 mm x 10 mm x 64 mm should be used. If, for any reason, the test specimen of 4 mm x 8 mm x 32 mm has to be used. This should be recorded.

9.4 The value of the transverse strength obtained in accordance with any of the test methods specified in **9.2** and **9.3** shall comply with the values declared by the manufacturer subject to the tolerance given in Table 1.

10 ASH CONTENT

10.1 General

The materials used for electrical brushes may contain relatively small amounts of other chemical elements and compounds. These may occur normally, as in some grades of natural graphite, or may purposely be added, as for example silicon carbide. These materials are grouped under the general category of 'ash'. They may have some influence on the performance in assisting film formation or providing 'scrubbing' action. It is therefore desirable to have a test method for the determination of ash content. It is used primarily by the manufacturer for production control. The procedure given in **10.1** to **10.4** is suitable for determination of ash content in brushes and brush material which do not contain metals.

10.2 Equipment

The following shall be required:

a) Furnace for temperature up to 1 000°C;

b) Equipment for regulating the temperature in the furnace;

c) Equipment for measuring the temperature up to 1 000°C;

d) Drying oven from temperature up to at least 110°C;

e) Thermometer for measuring temperature up to 110°C;

f) Desiccator with a suitable hygroscopic substance, for instance silica gel. The hygroscopic substance is to be renewed when necessary;

g) Shallow containers of a suitable size and material. They should be marked for identifications and heated to 1 000°C until their mass is stabilized. When not being used they shall be kept in the drying oven;

h) Tongs for moving the containers;

j) Analytical balance capable of weighing one container plus about 5 g of brush material with an accuracy of ± 0.000 2 g (0.2 mg);

k) Device for obtaining a sample of the material, for example, saw or drill; and

m) Spatula, pestle and mortar.

10.2.1 *Test Specimen*

Not more than about 5 g of brush material should be taken from manufactured brushes or brush block material which should be representative of the lot to be tested (1 or 2 g is usual for a sample taken from a brush).

The pieces should be granulated in a mortar until all particles are about 0.5 mm or less in all dimensions.

NOTE — Take every precaution in the preparation of sample to exclude every form of foreign matter.

10.3 Procedure for Non-metallic Brushes

The test specimen shall be dried in an oven at 100 ± 10°C to constant mass. This may take up to 2 hours.

A clean, dry container shall be weighed to within 0.2 mg.

The mass shall be recorded as G_1.

One to five grams of dried sample shall be added and the container plus sample shall be weighed to within 0.2 mg.

The mass shall be recorded as G_2.

The container and sample shall be put in the furnace and the temperature shall be increased slowly to at least 800°C, but not above 1 000°C.

During this period any recognizable odours (for instance phenol or sulphur) shall be noted and recorded.

Sample shall be burnt until no evidence of carbon remains.

NOTE — If all requirements mentioned above are fulfilled, 12 hour heating is sufficient for all materials to ensure complete ashing to constant mass.

The container shall be removed with its contents from the furnace. The container shall be covered while cooling until it reaches about 200°C and then transferred to a desiccator. Do not weigh until it reaches the ambient temperature in the balance room.

The container shall be weighed with its contents to within 0.2 mg.

This mass shall be recorded as G_3.

10.4 Calculation

The ash content is calculated as follows:

$$a = \frac{\text{Mass of residue}}{\text{Mass of original dry sample}} \times 100$$

$$= \frac{G_3 - G_1}{G_2 - G_1} \times 100 \text{ percent}$$

Unless otherwise agreed between the user and the manufacturer, at least 5 specimens shall be tested in accordance with **10.3**.

The arithmetical mean value of the results should be calculated and considered as the true ash content. The ash content in the form of range of values in a particular material may be declared by the manufacturer.

When required by the user, the values of ash contents or acid solubles (in case of grades containing metal and boron) shall be declared by the brush manufacturer. The true ash content should be compared with specified values and should be within the limits shown in Fig. 6.

NOTE — For the time being the limits given in Fig. 6 are for guidance only. These limits would be wider for electrographites containing metals, natural graphite grades, ungraphitised grades and resin bonded grades.

10.5 Test Procedure for Metallic Brushes

Becuase different methods of test for ash content in metal graphite brushes would be required depending on the presence or absence of major elements or compounds such as silver, tin, molybdenum (MoS_2), plastics, etc, no test method is prescribed here.

11 MEASUREMENT OF OPERATIONAL CHARACTERISTICS OF BRUSHES

NOTES

1 Attention should be drawn to procedure given in Annex B to achieve repeatibility in results.

2 The specification of test ring for determination of operational characteristics of cracks is given in Annex C.

11.0 Tables of Units, Symbols and Definitions

11.0.1 *Subscripts*

Subscript	*Reference*	*Example*
+	Positive polarity	U
–	Negative polarity	U
~	Alternating current or voltage	I ~ or U ~
B	Brush	J_B or I_B
C	Commutator or slip-ring	r_C
H	Brush-holder	r_H
r	Radial direction	H_r
t	Tangential direction	F_t
tot	Total values	U_{tot}
$\overline{\ldots}$	Mean values	W

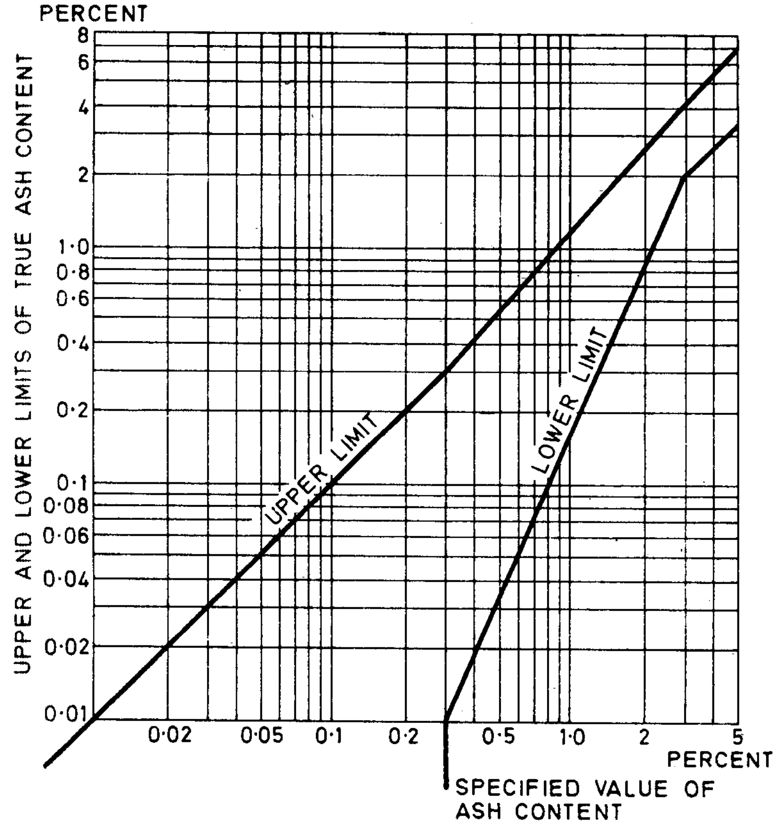


Fig. 6 Upper and Lower Limits of True Ash Content for Different Values of Specified Ash Content

11.0.2 *Geometrical Units and Symbols*

Symbol	*Name and Definition*	*Unit*
l, l_{tot}	Length, total sliding path	m
l, b, r, d, t, a	Dimensions in all drawings	mm
r_C	Radius of commutator or slip-ring	m mm
r_B	Radius of brush running surface	m mm
t, a, r	Dimensions of brush	mm
A	Area	m^2 mm^2
R_a	Surface roughness	µm
A_B	Brush surface area (sliding face)	m^2 mm^2
V	Volume	m^3 mm^3
N_B	Number of brushes	
k	Number of segments under a brush	
τ	Slot pitch	mm
h	Pitch of helical groove	mm
b	Slot width	m mm
r	Length of new brush	mm
r_t	Length of worn brush	mm
Δv	Brush volume worn away	mm^3
Δr	Brush length worn away $(r - r_t)$	mm
WR	Wear rate (volumetric) V/l_{tot}	m^3/m mm^3/m
WR*	Wear rate (linear) $\Delta r/l_{tot}$	m/m mm/m

11.0.3 *Electrical Units and Symbols*

Symbol	*Name and Definition*	*Unit*
U_{tot}	Total voltage drop per brush (from the Terminal to commutator or slip-ring)	V
U_{TOT}	Total voltage drop $U_{tot} + U_{tot}$ or $2\ U_{tot}$	V
U_S	Voltage drop in brush flexible	V mV
U_F	Connection voltage drop (flexible to brush)	V mV
U_B	Voltage drop in the brush	V mV
U_C	Contact voltage drop (brush to commutator or slip-ring)	V
I, I_B	Current, brush current	A
J_B	Brush current density	$A.m^{-2}$ $kA.m^{-2}$
R	Resistance (generally)	Ω mΩ kΩ
R_B	Brush resistance	mΩ
ρ_B	Brush resistivity	Ωm µΩm
R_V	Internal resistance (characteristic of voltmeter)	Ω/V

11.0.4 *Mechanical and Physical Units and Symbols*

Symbol	*Name and Definition*	*Unit*
F	Force (generally)	N
F_B	Force applied to the top of the brush	N
F_r	Radial component of a force	N
F_t	Tangential component of a force	N
$F\mu$	Friction force	N
m	Mass	kg
C	Weight	N
P_B	Brush pressure	kPa, $kN.m^{-2}$
T	Torque	N.m
P	Powder (generally)	W
P_o	Power input (test brushes lifted)	W
P_u	Power loss due to friction	W
μ	Coefficient of friction	
t	Time	s, min, h
t_s	Service time (*see* Annex D)	h
v	Velocity	$m.s^{-1}$
v_t	Circumferential (peripheral) velocity	$m.s^{-1}$
ω	Angular velocity	$rad\text{-}s^{-1}$
f	Frequency	Hz
n	Rotational speed	r.p.m. min^{-1}
θ_{amb}, I_{amb}	Ambient temperature	°C
θ, I	Temperature	°C
θ_B, I_B	Brush temperature	°C
θ_C, I_C	Temperature of commutator or slip-ring	°C
Δ_θ, Δ_I	Temperature rise	K
AH	Absolute humidity	$g.m^{-3}$
RH	Relative humidity	%
HB	Brinell hardness	
HR	Rockwell hardness (for brushes : HRB)	
HS	Scleroscope hardness	
HV	Vickers hardness	
EG	Electrographite brush grades	
NG	Natural graphite brush grades	
BG	Resin-bonded graphite brush grades	
HC	Hard carbon brush grades	
CG	Carbon-graphite brush grades	
MG	Metal-graphite and metal-impregnated brush grades	

11.1 Contact Drop Voltage

11.1.1 The total voltage drop from the brush terminal to the slip-ring or commutator is a complex parameter which is made up from the sum of the voltage drop shown in Fig. 7. Some of these voltage drops are not necessarily ohmic.

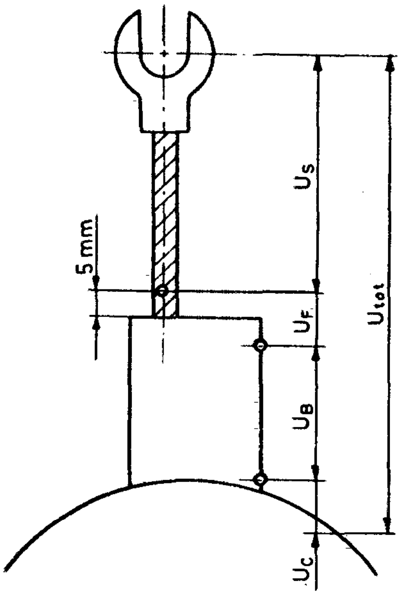


FIG. 7 TOTAL VOLTAGE DROP FROM THE BRUSH TERMINAL TO SLIP-RING OR COMMUTATOR

The coding for Fig. 7 is taken from IS 13586 : 1992.

U_{tot} = Total voltage drop between the brush terminal and slip-ring or commutator-U_{tot} is defined as the sum of all the individual voltage drops existing between the brush terminal and the slip-ring or commutator;

U_S = Voltage drop in the flexible (shunt);

U_F = Connection drop;

U_B = Terminal voltage drop of the brush; and

U_C = Brush contact drop.

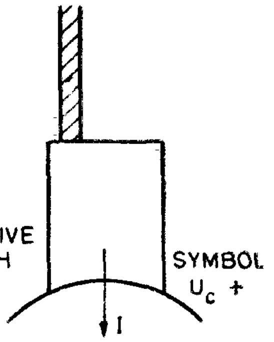
11.1.2 *Brush Contact Drop* (UC)

The brush contact drop is an operating characteristic of a brush and is normally non-ohmic and is influenced by external factors as well as the brush material characteristics.

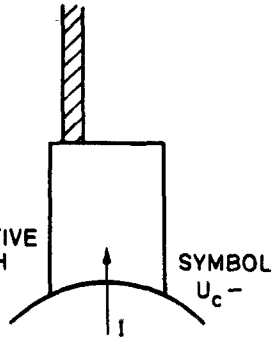
11.1.3 *External Factors*

These include, for example, brush pressure, current density, the material and surface condition of the slip-ring or commutator, humidity, temperature, atmosphere, peripheral speed, etc.

When brushes carry direct current, a different in contact drop voltage, U_C, may generally be observed between anodic and cathodic brushes and the slip-ring or commutator. The terms "anodic" and "cathodic" brush are defined in Fig. 8.



8A COMMUTATOR (OR SLIP-RING), NEGATIVE



8B COMMUTATOR (OR SLIP-RING), POSITIVE

FIG. 8 ANODIC AND CATHODIC BRUSHES

When brushes carry alternating current, these differences between contact drop voltages will not exist. The symbol for ac contact drop voltage shall be U_C.

11.1.4 *Measurement of Contact Drop Voltage*

11.1.4.1 *Instruments for measuring d.c. contact drop voltage*

Any d.c. voltmeter having an internal resistance of not less than 1 000 Ω/V is suitable. If a pointer type instrument is used then the minimum indication shall be not less than 20 percent of full scale deflection.

For normal measurements, an instrument of 2.5 percent (or better) accuracy will be adequate.

a.c. contact drop voltage should be measured with an instrument capable of measuring true rms. Such instrument are:

a) Thermal converter instruments (*see* IS 1248);

b) Ironless electrodynamic instruments (*see* IS 1248); and

c) Any electronic instrument capable of measuring true rms.

The internal impedance and accuracy shall be as specified in **11.1.4** above.

NOTE — Rectifier type millimetres are not recommended.

The contact voltage shall be measured by means of contact probes one connected to the brush and other to the rotating part.

The voltage probe to be applied to the rotating part shall be so constructed that it will have negligible influence on the value of the measured voltage.

Various acceptable methods of making this probe are available, for example:

a) A small metal-graphite brush running on the rotating part but clear of the test brush track(s);

b) A "brush" made from fire copper wires (brush flexible) applied in the same way as the metal-graphite brush [*see* item (a) above]; and

c) A mercury transmitted system.

NOTE — Whichever type of probe electrode is used, it is essential that the point of application to the rotating part shall be clear of the test brush track(s).

The brush contact probe shall be applied to the brush so that no disturbance of the brush operation is caused. For example, the probe may be permanently attached to the brush or to the brush-holder in such a way that contact is made with the side of the brush, or may be applied by hand.

The location of the contact probe on or in the brush shall be at a point not more than 5 mm from the sliding contact surface and at a distance of t_2 (*see* Fig. 9).

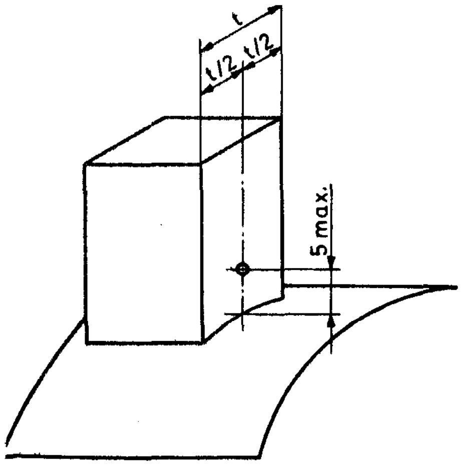


FIG. 9 LOCATION OF CONTACT PROBE

NOTE — If great accuracy is required for high resistivity material, ($p \geqslant 100$ µΩ m), a correction for U_C should be made to take account of the voltage drop between the probe location and the contact surface.

Alternatively, the brush contact drop may be calculated from the total single brush drop, by the following formula:

$$U_C = U_{tot} - (U_S + U_F + U_B)$$

The measurement of U_F is determined by the method detailed in Annex C. If, for any reason, two brushes are used for the measurement the total contact drop is:

$$U_{TOT} = U_{tot} + U_{tot}$$

For the measurement of U_{tot} (total single brush drop) the same voltmeter and the same ring probs are used as for measuring U_C, but in this case the brush probe shall be replaced by a pointed stainless steel probe which is applied to the brush terminal.

11.1.5 *Measurement of* $U_S + U_F + U_B$

A suitable millivoltmeter (accuracy class 2.5 percent or better) shall be used for this measurement, the selected range to give an indication of not less than 20 percent full scale deflection.

The measuring current shall be the same as that used to conduct the contact drop test and selected from the range of currents given in C-4. In view of the negligible errors introduced the effect of temperature rise may be ignored.

One voltage probe is to be applied to the brush body 5 mm above the sliding surface as specified in **11.1.4**. The other voltage probe, of pointed stainless steel, shall be applied to the brush terminal.

11.1.6 The value of contact drop voltage obtained by this test shall conform to the values declared by the manufacturer.

11.2 Measurement of Coefficient of Friction

The coefficient of friction µ is an operating characteristic of a brush influenced both by external factors and by brush material.

11.2.1 *External Factor*

These are as indicated in **11.1.3**.

Definition

The coefficient of friction µ is defined by the law of friction given by the formula (*see* Fig. 10):

$$\mu = \frac{F_t}{F_r} = \frac{F'_t}{F'_r}$$

where

μ = coefficient of friction;

F_r, F'_r = radial component of the forces acting at the interface; and

F_t F'_t = tangential component of the forces acting at the interface.

NOTE — Although there may be differences in the coefficient of friction due to the anodic and cathodic brushes, these are generally added together and only the average friction due to both brushes is measured.

11.2.2 *Measurement of Coefficient of Friction*

There are two main systems by which the coefficient of friction is usually measured:

a) Measurement of the tangential forces acting on the rotating surface; and

b) Measurement of the tangential forces acting on the brush.

11.2.3 *Measurement of the Tangential Forces Acting at the Brush Using Method* (a)

There are various methods of making these calculations but they all derive from the following basic concepts:

Symbols used in the equations which follow:

N_B = number of brushes

F_t, F'_t = tangential force per brush (N)

F_r, F'_r = radial force per brush (N)

r_C = radius of commutator or slip-ring m

T = torque (N.m)

P_μ = power loss due to friction (*W*)

P = power input when the brushes are in contact with the commutator or slip-ring (*W*)

P_O = power input when the brushes are not in contact with (are not rubbing on the commutator or slip-ring) (*W*)

ω = angular velocity (rad/s)

$$\mu = \frac{F_t}{F_r} \qquad (1)$$

$$T = N_B \times F_t \times r_C \qquad (2)$$

$$P = T \times \omega \qquad (3)$$

$$P\mu = P - P_O \qquad (4)$$

$$\mu = \frac{P - P_o}{N_B \times F_r \times \omega\ r_C} \qquad (5)$$

The simplified sketch in Fig. 11 should clarify the method of measuring the coefficient of friction, using method (a).

From equation (4) :

Measure P after stable running conditions have been achieved and then, at the same angular velocity, measure P_O, using a wattmeter or voltmeter/ammeter.

All measurements shall be made with instruments having accuracies of 2.5 percent or better.

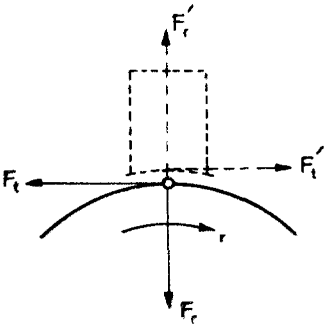


FIG. 10 ILLUSTRATION OF COMPONENTS OF FRICTIONAL FORCE

NOTE — For results demanding higher accuracies, inherent driving motor losses should be taken into account when calculating the coefficient of friction.

11.2.4 *Measurement of Tangential Forces Acting at the Brush, Using Method* (b)

There are many suitable mechanical systems which may be used for making this measurement and all should be acceptable provided the instruments used have inherent accuracies of 2.5 percent or better (*see* Annex E).

Whichever system is used, it shall have negligible effect on the mechanical stability and electrical performance of the brush.

11.2.5 The value of coefficient of friction obtained by this method shall conform to the declared value of manufacturer.

11.3 Measurement of Brush Wear

11.3.1 *Brush Wear*

Brush wear *WR* is a characteristic of brush material which is affected by electrical, mechanical and external conditions.

11.3.1.1 Brush wear rate is given by the following formula:

$$WR = \frac{\Delta r \times A}{l_{tot}}$$

(The calculation from which this formula is derived is given in Annex C)

where

A = brush cross-sectional area (m^2)

WR = mean wear rate (volumetric) (m^3/m)

Δ_r = mean Δ_r measured at different points on the brush surface (m)

l_{tot} = distance travelled by the track under the brush (m)

If the cross-section of the brush is considered to be constrant, then the formula gives above becomes the following:

$$\text{mean wear rate (linear) } WR^* = \frac{\Delta_r}{l_{tot}} \text{ (m/m)}$$

where

WR^* is the mean linear wear rate of the brush.

The linear wear rate is the most practical method for expressing brush wear rate.

11.3.1.2 The units in which brush wear may be expressed will largely be governed by the nature of the brush application.

11.3.1.3 The brush wear velocity (wear rate) is commonly expressed by the following units:

a) mm/1 000 h (mm of brush wear/1 000 working h); and

b) mm/Mm (mm of brush wear/track Mm).

Conversely, brush life is usually expressed in the units:

a) h/mm (working hours/millimetres brush wear); and

b) miles/in (track miles/inches of brush wear).

NOTES

1 Whatever the time of testing, the result should be expressed in the above units.

2 This test does not apply to routine testing of the machines.

11.3.2 *Measurement of Brush Wear*

The initial and final measurements of brush length should be made at precisely the same position on the brush or a line parallel to the "*r*" axis using, if possible, the same measuring instrument, or otherwise an instrument of the same accuracy (*see* Fig. 12).

The choice of instrument, micrometer, varnier caliper or depth gauge, used to make the measurement will largely depend on the amount of wear which has occurred.

The instrument used shall enable the wear to be measured to ± 2.5 percent or better.

To measure brushes of difficult shape a suitable jig to fit in the micrometer could be constructed to ensure positive location of the brush to be measured.

Furthermore, the choice of micrometer anvil shape depends on the profile of the shape to be measured.

11.3.3 The value of brush wear obtained by this test shall conform to the values declared by the manufacturer.

NOTE — The brush wear may differ in actual operation as this value is under laboratory conditions. The wear of commutators and slip rings is equally important.

12 MARKING

12.1 The following particulars shall be legibly and indelibly marked on each block of brush material:

a) Grade of carbon block;

b) Indication of source of manufacture; and

c) Batch number and year of manufacture.

12.2 The carbon brush material (blocks) may also be marked with Standard Mark.

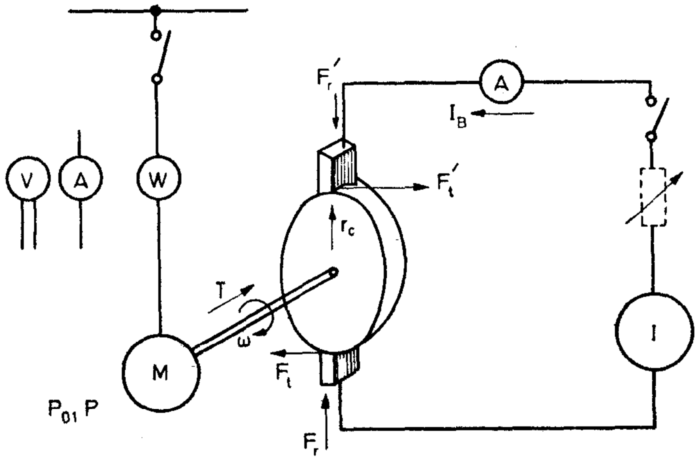


FIG. 11 SKETCH SHOWING METHOD OF MEASUREMENT OF CO-EFFICIENT OF FRICTION

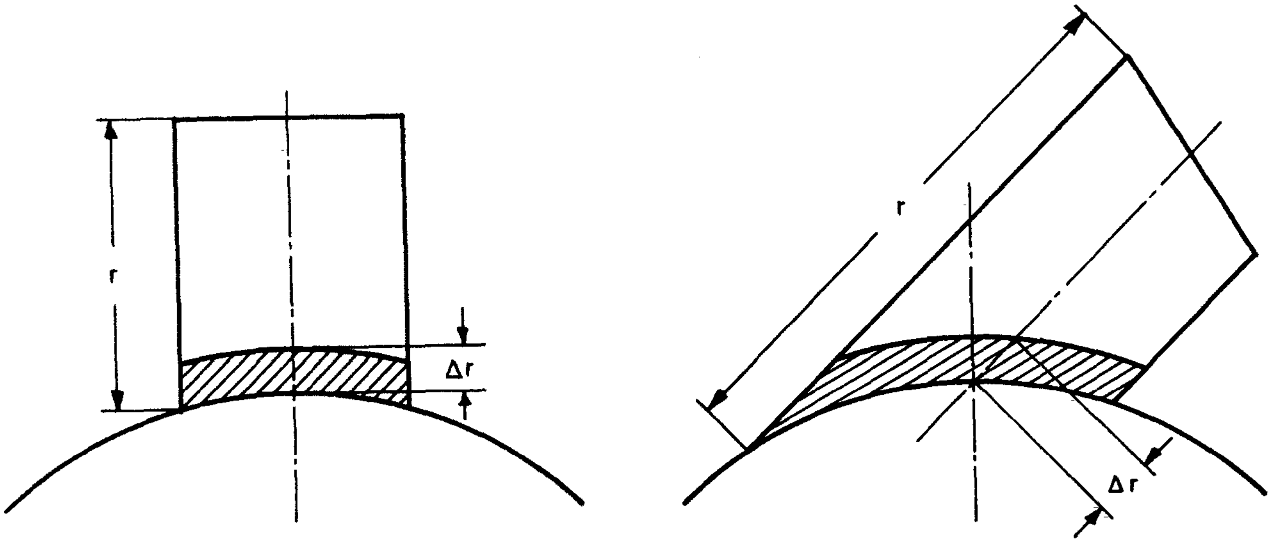


FIG. 12 MEASUREMENT OF BRUSH WEAR

13 PACKAGING

13.1 The carbon blocks may be suitably packed so as to avoid any damage during transit.

14 INFORMATION TO BE GIVEN WITH ENQUIRY OR ORDER

14.1 The purchaser should supply the requisite information on grade, application of brush material.

14.2 A recommended proforma containing technical questionnaire on carbon brushes as given in IS 9919 : 1981 should be referred for ordering the carbon blocks.

ANNEX A

(*Clause* 2)

LIST OF REFERRED INDIAN STANDARDS

IS No.	*Title*
919 (Part 1) : 1963	Recommendations for limits and fits for engineering: Part 1 General engineering
1248 (Part 1) : 1983	Direct acting indicating analogue electrical measuring instruments and their accessories: Part 1 General requirements (*second revision*)
9919 : 1981	Guide for selection and use of carbon brushes for applications in rotating electrical machines
13586 : 1992	Definitions and nomenclature for carbon brushes, brush-holders, commutators and slip-rings for rotating electrical machinery [*superseding* IS 3003 (Part 1) : 1977]
13466 : 1992	Brushes for electrical machines [*superseding* IS 3003 (Parts 3 & 4) : 1977]

ANNEX B

(*Clause* 11, *Note* 1)

DISCUSSION OF PROBABLE ACCURACIES AND REPEATABILITY OF OPERATIONAL CHARACTERISTICS MEASUREMENTS

B-1 In view of the nature of the brush material, changes within the recommended ranges of ambient conditions, etc, absolute repeatability of test results is not to be expected.

B-2 If all controllable parameters are accurately maintained, repeat tests carried out on the same machine with the same brush sets shall give accuracy versus repeatability of coefficient of friction, contact drop voltage and brush wear within, say, ± 10 percent for each measurement compared with the average results found on previous tests. The above remarks assume that the same test procedure has been strictly followed.

B-3 It is also suggested that sets of test brushes in various materials are reserved for machine calibration tests. Before each test, it is recommended that the connection millivolt drop (*see* **15.6.1**) of Doc : ETDC 15(3102) be monitored and that the connections be re-made if significant changes in connection millivolt drops are found.

ANNEX C

(*Clause* 11, *Note* 2)

SPECIFICATIONS OF TEST RING

C-1 GENERAL

C-1.1 It is possible that no single test rig can accommodate all the required application parameters; it therefore follows that more than one type of test rig would be required. These test rigs shall be so constructed that, relative to the quantities to be measured (*see* **11.1**, **11.2** and **11.3**), the required brush operating parameters may be easily and accurately obtainable.

C-1.2 It should be appreciated that, because of the many variables involved and the fact that this equipment is "non-commutating", absolute values obtained from such test machines will differ from those obtainable from "real" machines. Moreover, for the above reasons and because of differing ambient conditions, identical results may not be obtainable from test rigs of similar design and construction.

C-2 TEST RINGS FOR BRUSHES USED ON COMMUTATING MACHINES

C-2.1 Test Rings

For the reasons given in **B-1**, it is not possible, to specify a single "standard" test machine, but machines constructed within the framework given below should be capable of producing satisfactory results.

C-2.1.1 *Material for Test Rings*

The test ring shall be constructed of copper and should have a hardness of HV 85 to HV 110 (Vickers diamond pyramid scale) or HB 80 to HB 105 on the Brinell (steel ball) scale of hardness.

C-2.1.2 *Dimensions of Test Rings*

The diameter of the test ring shall not be less than 200 mm or more than 300 mm. Axial slots, evenly spaced on the surface of the ring shall be cut to give a slot pitch τ of 5.0 mm to 7.5 mm.

The relationship between the tangential dimension t of the brush and the number of segments spanned by the brush to eliminate the risk of mechanical resonance shall be:

$$k\tau \neq q \quad (\textit{see} \text{ Fig. } 13)$$

where

k is a whole number equal to 2, 3 or 4 and
q is a variable number such that $t - b \leqslant q \leqslant t + b$

where

t = brush thickness, and
b = slot width.

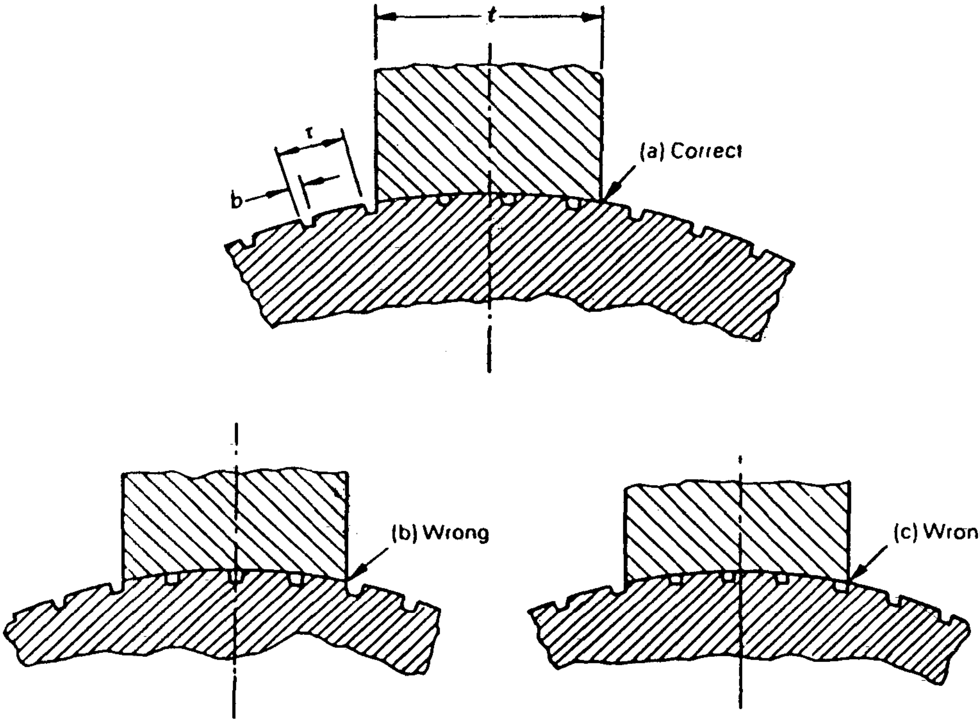


FIG. 13 TEST RING

The width b of the slots shall be between 0.8 mm and 1 mm and their depth between 1 mm and 3 mm.

The axial length of the slotted ring shall be equal to a dimension of the test brush, plus at least 6 mm.

C-2.1.3 *Preparation of the Test Ring*

The following conditions shall be set :

a) Each segment shall have the same radius as that of the whole ring (*see* Fig. 14);

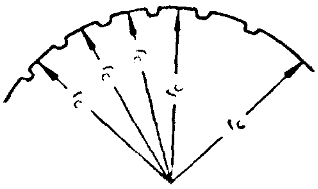


FIG. 14 SEGMENT OF TEST RING

b) The geometrical deformation of the ring and the run-out when rotating slowly in its own bearings shall not produce a depth gauge deflection of greater than 0.01 mm. Furthermore, at operating speed there shall be no significant vibration due to unbalance. The test shall be carried out at a speed other than the critical speed;

c) This order of accuracy shall be achieved if the ring is turned with a diamond or correctly shaped tungsten carbide tipped tool at a speed as near as possible to the highest test velocity, the ring being mounted in its own bearings. All "burrs" and swarf shall be removed from the slots and slot edges before the test; the minimum amount of metal only shall be removed during this clearing process in order to prevent the formation of bevels on the slot edges;

d) The use of abrasive paper or cloth to remove tool marks and/or a very high surface polish shall be limited in order to avoid "doming" the segments (*see* Fig. 15); and

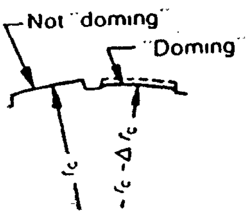


FIG. 15 SEGMENT "DOMING"

e) The degree of roughness R_a (*see* Fig. 16) should lie between the limts $0.8\ m\,\mu\ R_a \leqslant$ 1.2 µm.

The curve C represents the profile of a surface roughness over the length L.

where

D = mean line such that $\Sigma S_1 = \Sigma S_2$

R_a = arithmetic mean of the curves between C and D and is the mean height of h obtained from the heights $h_1, h_2, h_3 \ldots h_n$ always taken with the sign+:

$$R_a = \frac{1}{L}\int_0^L |h| dL \approx \frac{h\ |h_1| + |h_2| + \ldots + |h_n|}{n}$$

The degree of roughness may be readily obtained by a light application of suitable fine grade of commutator dressing stone to the ring surface.

C-2.2 Brushes

C-2.2.1 Preferably, four brushes equally spaced around the test ring shall be used, as indicated in Fig. 17.

The brushes shall be of alternate polarity.

If for any reason, it is necessary to operate with two brushes only, then the angular spacing between them should be 90° or 180°.

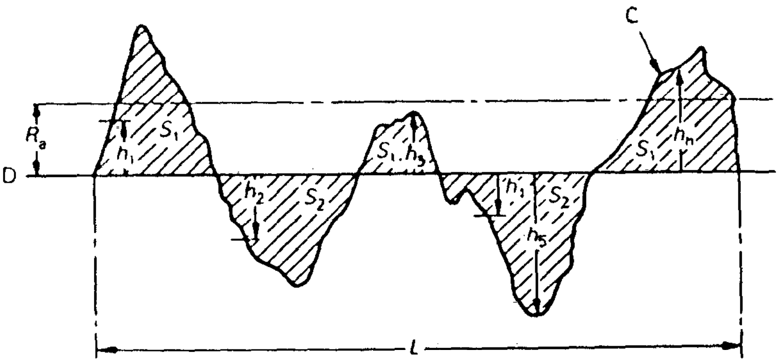


FIG. 16 DEGREE OF ROUGHNESS R_a

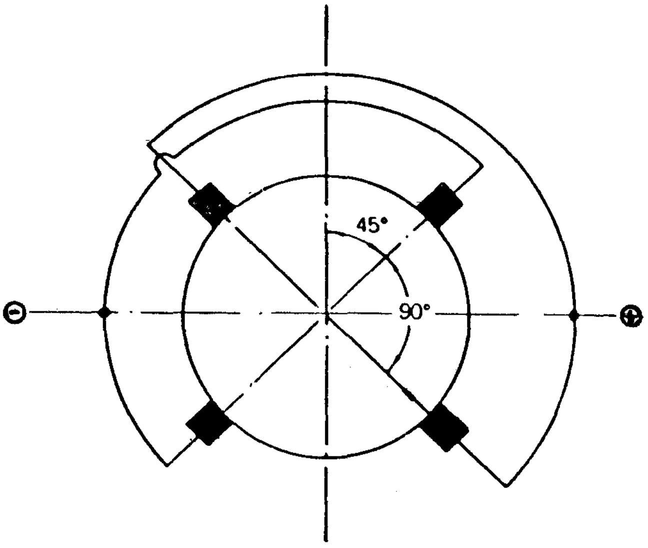


FIG. 17 SPACING OF BRUSHES ROUND TEST RING

If the axis of the ring is horizontal, the brush location shall be as indicated in Fig. 16. The positioning of the brushes becomes less critical if the axis of the ring is vertical.

C-2.2.2 *Dimensions of Test Brushes*

Dimension	*Brush Grade* (*see* 11.0)		
	EG-NG-MG	BG	CG-HC
t	12.5, 16, 20	10, 12.5	10, 12.5, 16
a	25	25	25
r	40	40	40

NOTE — All dimensions are in millimetres.

The brushes shall be made with a 7.5° bevel angle (trailing attitude) to improve the mechanical stability.

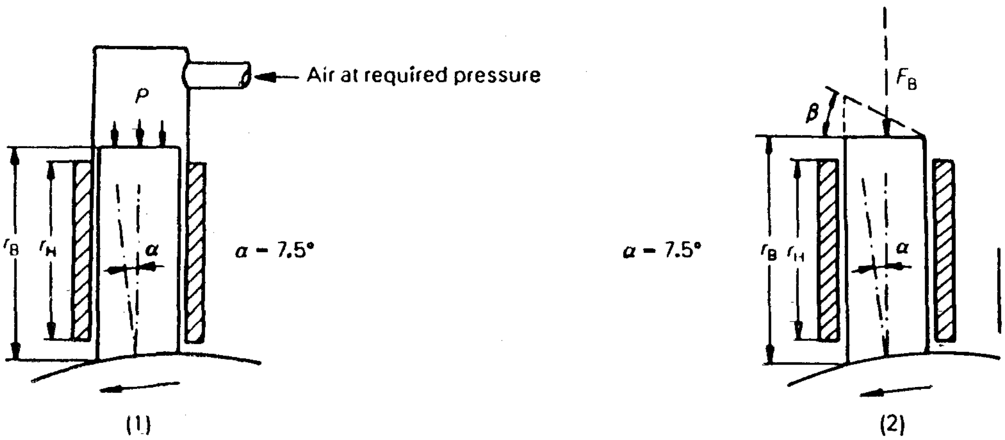
C-2.3 Test Brush Holders

C-2.3.1 Brush holders shall be substantially constructed and rigidly affixed to the machine so that they are free from vibration under the most adverse conditions, and of such design that they will not influence the stability of contact between test brush and test ring.

C-2.3.2 The dimensions *a* and *t* of the trailing brush holder shall be suitable for brushes as indicated in **C-2.2.2**.

The r_H dimension of the brush holder shall be not less than 0.75 *r* (*r* = dimension of a new brush).

C-2.3.3 The brush holders shall be such that the force is applied in the radial direction *r* of a brush with zero top bevel; and the required pressure shall be to a tolerance of ± 5 percent. The system used for obtaining the required brush pressure shall be capable of fine adjustment (*see* Fig. 18).



(1)

(2)

FIG. 18 PRESSURE ON BRUSHES

If system (1) is adopted, the air supply shall be substantially free from water and/or oil. If greater mechanical stability is required for satisfactory brush operation, a top bevel angle of β not more than 22.5° may be employed. In this case, also the true brush force shall be measured along with r axis of the brush.

C-3 TEST RINGS FOR BRUSHES USED ON NON-COMMUTATING OR SLIP-RING MACHINES

C-3.1 These rings may be manufactured of bronze, copper or steel. The use of alloys containing zinc, silicon, lead, aluminium, chromium, etc, may cause inferior brush operation, and shall be avoided where possible. Together with the test results, the mechanical characteristics of the ring should be stated.

C-3.1.1 *Dimensions of Test Slip-Rings*

The following shall be ensured:

a) These rings shall be not less than 200 mm or more than 300 mm diameter and may be plain or helically grooved. If helically grooved, the configuration of Fig. 19 shall be used:

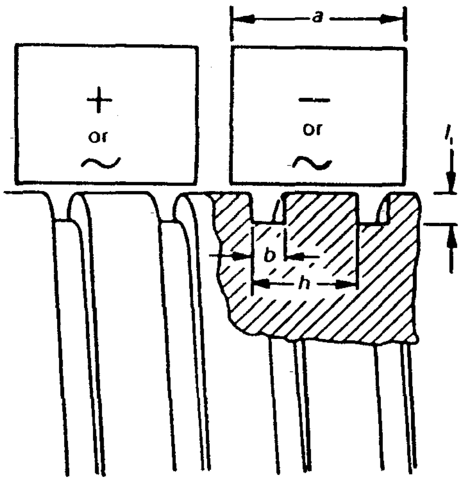


FIG. 19 TEST SLIP RING (GROOVED)

b) The groove shall be "single-start" and the depth l_r of the slot shall be between 4 mm and 5 mm and not permitted to go below 1.5 mm; and

c) For a brush having a dimension of 25 mm, h shall be 12.5 mm in order to avoid pulsations of brush pressure.

The groove width b should lie between $\frac{h}{3}$ and $\frac{h}{4}$.

NOTE — It is appreciated that asynchronous motor slip-rings use a brush having the t dimension greater than the a dimension. It is suggested that, for this comparative testing and to maintan the standardization of test apparatus, the same holders as recommended for "commutator" motor test brushes be used. Those having the largest t dimension are to be preferred.

C-3.1.2 *Preparation of Test Rings*

The following conditions are recommended:

a) *Quality* — This should be to the same specification as indicated in item (b) of **C-2.1.2** that is both plain and helically grooved rings to have a maximum regular eccentricity (ovality) not greater than 0.01 mm when measured turning slowly in its own bearings using a suitable depth gauge;

b) Plain bronze or copper rings to be turned as indicated item (c) of **C.2.1.3**;

c) *Steel rings* — These rings shall be re-surfaced by grinding, using a rigidly mounted, preferably independently driven grindstone rotating in the opposite direction to that of the slip-ring which itself shall rotate at normal test speed. A medium grit wheel shall be used.

   Before the test, all burns and swarf shall be removed from the slots and slot edges. The sharp edges of the slots and their burrs can be removed with a good quality abrasive stone, that is, with an alumina base of which the grain size is finer than 220.

d) The surface finish shall be to the degree of roughness as specified in item (e) of **C-2.1.3**.

C-3.2 Arrangement of Brushes

C-3.2.1 For d.c. operation, each brush polarity shall run on its own track.

A minimum of two brushes per track shall be used. If more than this number of brushes per track is used, they shall be uniformly spaced around the slip-ring and in no case shall the total brush surface area exceed 20 percent of the surface area of the track.

NOTE — In purely comparative testing it is considered that the use of "trailing" aspect brush holders would not be deleterious and would reduce the number of brush holder types required.

C-3.3 Operating Conditions

C-3.3.1 The calculation of brush pressure and brush current density shall be the same as for plain rings, that is, the effect of a helical groove on these quantities shall be ignored.

C-4 TEST SCHEDULES AND OPERATING CONDITIONS

C-4.1 General

C-4.1.1 The test brushes shall be of the same grade. The connection drop U_F of the test brushes shall be measured prior to testing, and four brushes of similar connection drop values should be selected for test with a tolerance of not more than ± 20 percent.

C-4.1.2 Prepare the test ring as indicated in item (a) to (e) of **C-2.1.3** and item (a) to (d) of **C-3.1.2.**

C-4.1.3 Bed the test brushes to the ring with firstly medium and then fine silicon-oxide or aluminium-oxide or other non-conducting abrasive paper or cloth. It is essential to remove from the ring all traces of patina(skin) remaining from the previous test with fine abrasive paper. Thoroughly clean the test ring, brushes and brush boxes after these operations.

C-4.1.4 Set the specified pressure on the brushes (*see* Table 4).

C-4.1.5 Brush "bedding" shall then be commenced at the specified conditions of speed and current density for the test. During this period, close observation shall be made to ascertain that no abnormal brush performance occurs (chattering, ring grooving, sparking, ring blackening excessive ring temperature, etc). These phenomena can adversely affect the test.

C-4.1.6 "Bedding" shall be continued for 24 h minimum and until stable μ and U_C readings have been obtained for at least three consecutive hourly readings.

At this point, all brush contact surfaces shall be examined to determine that the brushes are in fact, fully bedded, that is, the brush surfaces are uniformly well polished.

If these appear satisfactory, the machine shall be stopped and the test ring examined to see that a substantially uniform patina (skin) has been developed.

C-4.1.7 When bedding has been satisfactorily concluded, all the brushes shall be numbered and their *r* dimension measured. It is most important that each brush be then replaced in exactly the same manner and in the same brush box it occupied in "bedding" and that the brush pressure system be replace on the head of the brush in exactly its previous position.

C-4.2 Test Procedure

C-4.2.1 A test of minimum 100 h duration (after bedding) may be sufficient if brush wear measurements are not required. If, however, brush wear measurement is required, this period shall be extended to 150 h at least, in order that a more accurate determination of brush wear can be made.

C-4.2.2 Prior to each measurement of μ and U_C, the test brush current and ring speed should be checked and re-adjusted, if necessary.

If recording instruments are not used for the measurement of μ and U_C readings of drive motor voltage, current and U_C should be made with pointer or digital instruments at intervals of at least 2 h. If necessary, this time interval may be reduced or increased. At the same time as the above, measurements are made, room brush and ring temperatures shall be recorded, if possible.

NOTE — Brush temperature can be measured by means of a fine thermocouple. The "bead" of the thermocouple, or other method ensuring the required measurement accuracy, being located at 5 mm from the running face of the brush and approximately 5 mm distance inwards from the side of the brush, as indicated in Fig. 8.

The thermocouple wires can also serve as one voltmeter probe for measuring U_C (*see* Annex F for other methods of measuring temperatue).

C-4.2.3 Current distribution between test brushes shall be examined at the same time as μ and U_C are measured. Any suitable test measuring device can be used. One simple method could be by the measurement of the voltage drop in the brush flexible cable with a suitable millivoltmeter.

C-4.2.4 The humidity of the test room atmosphere shall be recorded daily.

C-4.2.5 Observations of sparking, chatter, vibration, etc, shall be made at the same time as μ and U_C are measured, or two or three times daily if recording instruments are used to obtain μ and U_C.

C-4.2.6 The test brush(load) current and rotational speed shall be maintained at ±5 percent of the specified values.

C-4.2.7 At the end of each test, accurate brush and ring surface descriptions shall be recorded.

C-4.3 Test Conditions

C-4.3.1 The test conditions listed in Table 4 are "medium" conditions likely to be met on non-specialized machines.

C-5 CURRENT SOURCES FOR TEST BRUSHES

C-5.1 Direct Current Supply

C-5.1.1 *d.c. Generator*

To be capable of supplying the maximum likely demand when a stabilizing ballast resistance is included in the test brush circuit; alternatively, a constant-current source of short time constant, such as a welding generator, may be used.

C-5.1.2 *Diode Rectifier*

Fed from an ac source and capable of supplying the maximum likely demand. Current ripple shall be defined as follows:

$$\text{Ripple factor } K_O = \frac{i_{max} - i_{min}}{i_{max} + i_{min}}$$

The ripple factor (K_O) (*see* Fig. 20) shall not exceed 0.10 (10 percent). This value should be recorded for each test.

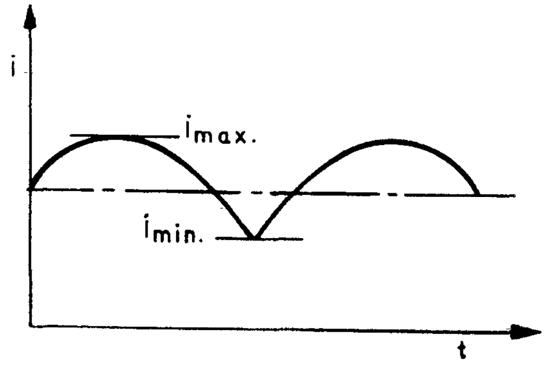


FIG. 20 RIPPLE FACTOR

C-5.1.3 *Controlled Rectifier (As for* C-5.1.2)

NOTE — Whichever type of power source is chosen, it should be capable of maintaining the selected load current to within ± 5 percent of the required value for the test in progress and have a quick response to changes of contact voltage.

C-5.2 Operation of Test Brushes with Alternating Current

C-5.2.1 This may be achieved by a controllable constant current source, for example, a welding transformer suitable for operating from the local frequency (40 Hz to 60 Hz).

The transformer chosen shall produce a sensibly pure sine wave output over the required current range.

Table 4 Pressure Test Conditions

(*Clauses* C-4.1.4 *and* C-4.3.1)

Symbol	Name	Unit	Eg	RB	HC-CG	NG	MG
t	Tangential dimension	mm	12.5, 16, 20	10, 12.5	10, 12.5, 16	12.5, 16, 20	12.5, 16, 20
a	Axial dimension	mm	25	25	25	25	25
r	Radial dimension	mm	40	40	40	40	40
V_t	Peripheral speed	m/s	25 to 55	25 to 35	10 to 25	25 to 55	10 to 25
J_B	Current density	A/m^2	10 to 12.5 × 10^4	6 to 10 × 10^4	6 to 10 × 10^4	8 to 12.5 × 10^4	19.5 to 24.5 × 10^4
P_B	Brush pressure	kPa kN/m^2	18 to 22	18 to 22	15 to 18	13 to 20	20 to 25
$Q_C I_C$	Actual ring temperature	°C	80 to 100	80 to 100	80 to 100	80 to 100	80 to 100
AH	Absolute humidity	$g(H_2O)m^{-3}$	8 to 12	8 to 12	8 to 12	8 to 12	8 to 12
AH	Absolute humidity	$g(H_2O)kg^{-1}$	—	—	—	—	—

NOTE — All these should be carried out in an atmosphere substantially free from dust, chemical vapour, etc.

ANNEX D

(*Clauses* 11 *and* 11.3.1.1)

DETERMINATION OF A FORMULA FOR BRUSH WEAR RATE

D-1 Many different practical units to indicate brush wear are in current use as shown in **11.3.1.3**.

D-1.1 These various units may be convenient for indicating brush wear under specific applications but all ignore the basic principles of brush wear which should be derived.

D-2 Brush wear is an empirically derived working parameter of a brush under given operational conditions which shall, in any case, be specified and it is also necessary to define how test result variations due to brush polarity and position will be resolved.

D-2.1 In given working conditions, a small volume dV of the brush is eroded from a small area of brush dA when sliding a distance dl on a slip-ring or commutator (*see* Fig. 21).

The volume, $dV = da \times dt \times dr$ is worn away.

This volume dV is proportional to the path length dl measured in the direction of sliding.

$$dV = W \times dl = da \times dt \times dr \qquad \text{...(1)}$$

where

W is the factor of proportionality and may not necessarily be constant over the whole brush surface area at any given moment and may also vary within a wide range along the observed total sliding path l.

Thus, Vl over the total path l becomes:

$$Vl = \int_a \int_t \int_r dA \times dr = \int_a \int_t \int_l W \; dl \qquad \text{...(2)}$$

where

$dr = f_1 \; (a, \; t)$ and $W = f_2 \; (a, \; t, \; l)$

These integrals may be solved assuming that:

i) Over a sufficiently long time interval or sliding path length, the brush will wear uniformly over the whole area $A = a \times t$; and

ii) A proportionality factor W averaged over the total sliding path t is introduced.

From these assumptions, "Vl" becomes:

$$Vl = A \times \Delta r + Cr = W \times l + C_a + Cl \qquad \text{...(3)}$$

where

C_r, C_a and Cl are constants of integration.

For $l = O....C_r$ becomes O and $C_a = -Cl$, thus

$Vl = A \times \Delta r = W \times l$ or

$$\frac{Vl}{l} = \frac{A \times \Delta r}{l} \quad W \text{ with } A = a \times t \qquad \text{...(4)}$$

W is the wear rate with its units (m^3/m) for which the symbol WR is chosen.

D-3 The total sliding path l for a brush running on a slip-ring or commutator of radius r_c at a rotational speed of n rev/min and service time t_s is:

$$L = V_t \times t_s \times 3\,600 = 120 \times r_C \times \pi \times n \times t_s \qquad \text{...(5)}$$

where

r_C = radius of commutator or slip-ring (m);

n = rotational speed (rev/min); and

t_s = service time (h).

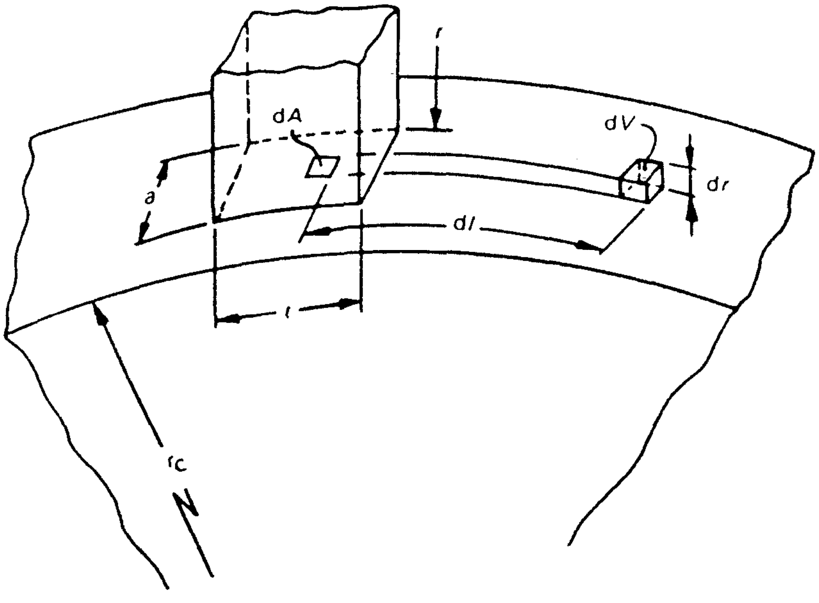


FIG. 21 LINEAR BRUSH WEAR

ANNEX E

(*Clause* 11.2.4)

THE DYNAMOMETER AS AN ALTERNATIVE TEST MACHINE FOR THE MEASUREMENT OF THE COEFFICIENT OF FRICTION

E-1 HINTS ON THE DESIGN OF A DYNAMOMETER

Figure 22 shows the fundamental design of a dynamometer.

1) The axes of the rotating slip-ring and the brush holder support ring shall be made as concentric as possible;

2) The dynamometer assembly shall be mechanically "stiff" (that is, rigid) and have the maximum possible mass in order to provide adequate damping of the high frequency vibrations generated by the brushes under test;

3) Great care shall be taken to ensure that the friction of the brush holder support ring bearings is minimal in order that the measured brush friction force is not adversely affected;

4) The angular movement of the brush holder support ring shall be restricted so that the relative tangential movement of the brush to cage should not exceed 0.5 mm; and

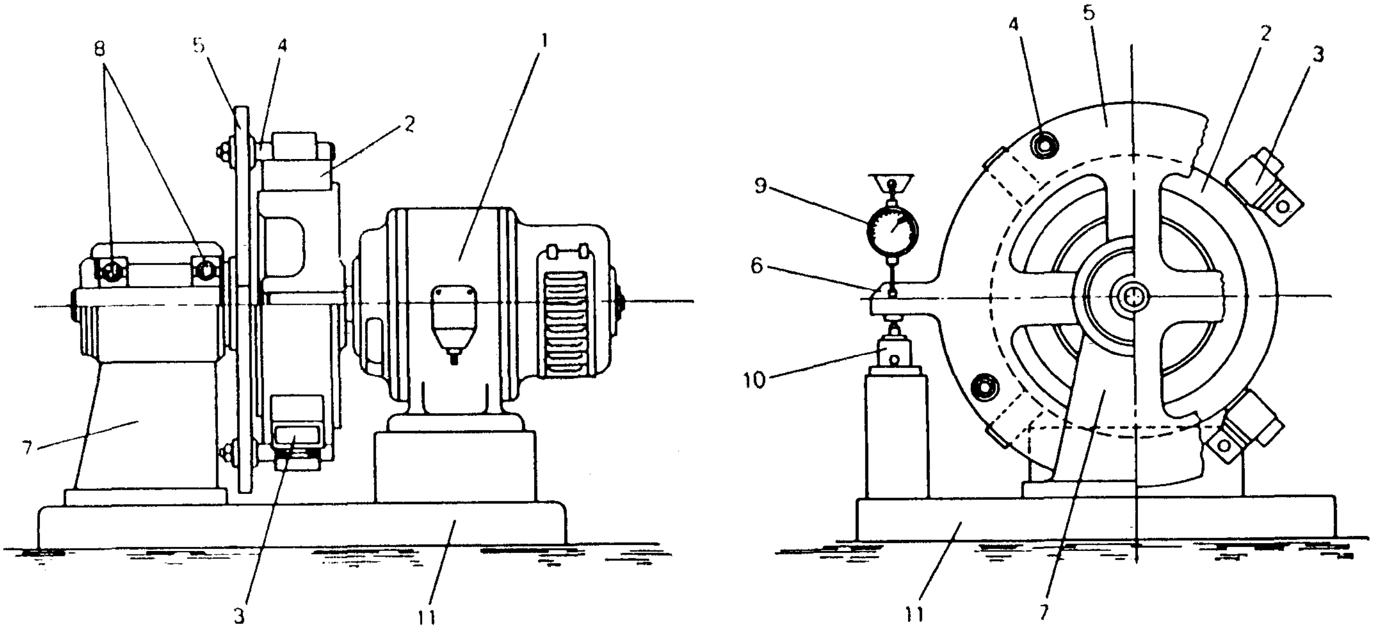
5) There are, now-a-days, many acceptable systems, both mechanical and electrical available for measuring the brush friction force, and one suitable for the design of the dynamometer should be available for the following:

   a) Strain gauge
   b) Displacement transducer
   c) Load cell
   d) Differential transformer

   These are suitable for use with recording instruments

   e) Lever and weights
   f) Spring balance

   For spot readings



1 D.C. motor or variable speed drive
2 Testing
3 Brush holder and brush
4 Brush holder support spindle
5 Brush holder support ring
6 Dynamometer lever
7 Dynamometer bearing housing and pedestal
8 Dynamometer bearings
9 Force measuring device (spring balance)
10 Electric load cell
11 Base plate

FIG. 22 BRUSH TEST MACHINE (DYNAMOMETER)

ANNEX F

(*Clause* C-4.2.2, *Note*)

MEASUREMENT OF TEMPERATURE OF BRUSHES, TEST RING AND ATMOSPHERIC HUMIDITY

(There are several methods by which the above-mentioned quantities may be measured.)

F-1 BRUSH TEMPERATURE

F-1.1 The brush temperature may be measured by the insertion of three thermocouples in the brush as indicated in Fig. 23.

The temperature at the brush/ring interface may be extrapolated with a reasonable degree of accuracy from the readings from the three embedded thermocouples (*see* Fig. 24).

F-2 RING TEMPERATURE

F-2.1 If possible, a cooling curve of temperature versus time should be made for each test machine. This curve, which is exponential in form, may be extrapolated back to $t = O_s$, with a fair degree of accuracy.

Temperature measurements can be made with:

a) A thermocouple (surface pyrometer) for which a suggested design is given in Fig. 25;

b) A resistant thermometer; and

c) Alternatively, a thermocouple may be embedded within the ring, and the wires brought out to two auxiliary measuring slip rings mounted coaxially to the test ring.

If this method of measurement is adopted, the auxiliary slip-rings shall be made of copper, silver-plated copper or silver and made to the smallest practical diameter.

The output voltage of the thermocouple shall be collected by not less than two silver-graphite brushes per ring.

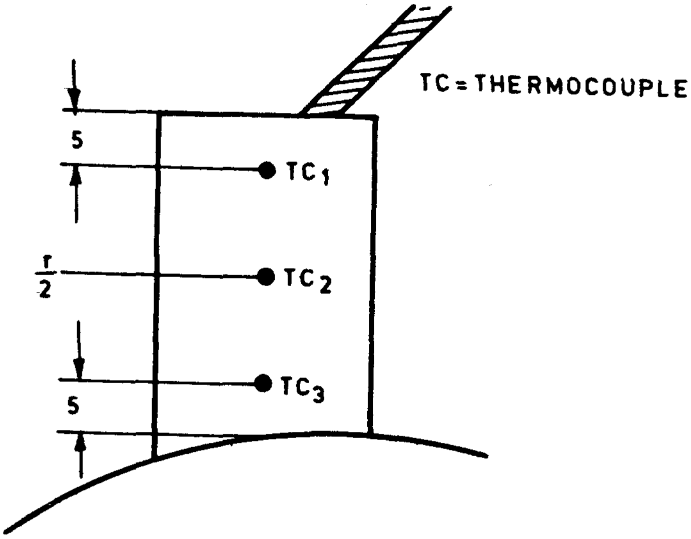
These auxiliary slip-rings shall be protected from external thermal effects.

F-3 MEASUREMENT OF ATMOSPHERIC TEMPERATURE AND HUMIDITY

F-3.1 The psychrometric (wet and dry bulb thermometers) method is probably the simplest way of obtaining both relative and absolute humidity, when used with an appropriate conversion chart (*see* Fig. 26). This method will give the absolute humidity in $g(H_2O)/m^3$ air and shall be corrected to 25°C and a pressure of 1 bar.

The psychrometer shall be operated in still air and adjacent to the machine under test.

A lesser unit is $g(H_2O)$/kg dry air. This unit can also be obtained from the conversion chart from normal psychrometric readings.



All dimensions in millimetres.

FIG. 23 POSITIONING OF THERMOCOUPLE

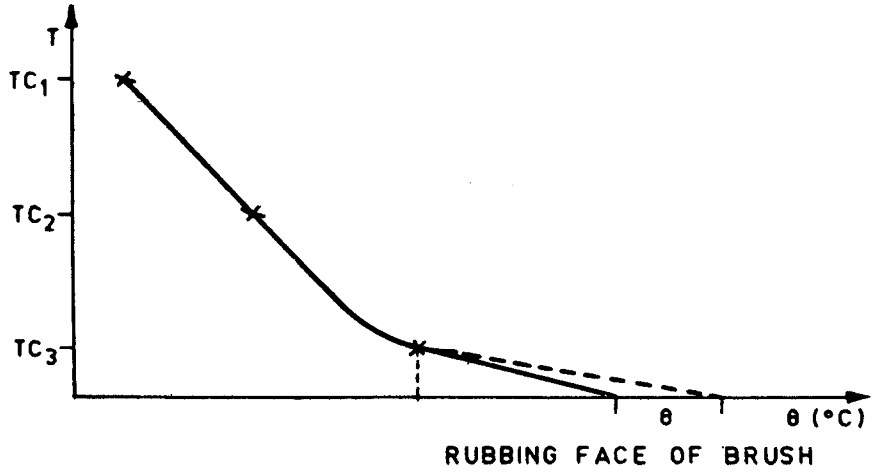
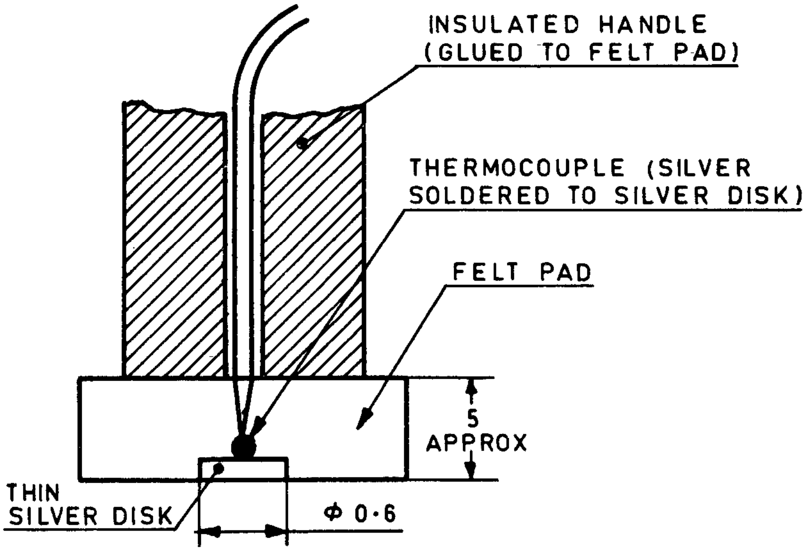


FIG. 24 TEMPERATURE GRADIENT OF BRUSH


INSULATED HANDLE (GLUED TO FELT PAD)
THERMOCOUPLE (SILVER SOLDERED TO SILVER DISK)
FELT PAD
5 APPROX
THIN SILVER DISK
Φ 0·6

All dimensions in millimetres.

FIG. 25 TYPICAL DESIGN OF THERMOCOUPLE

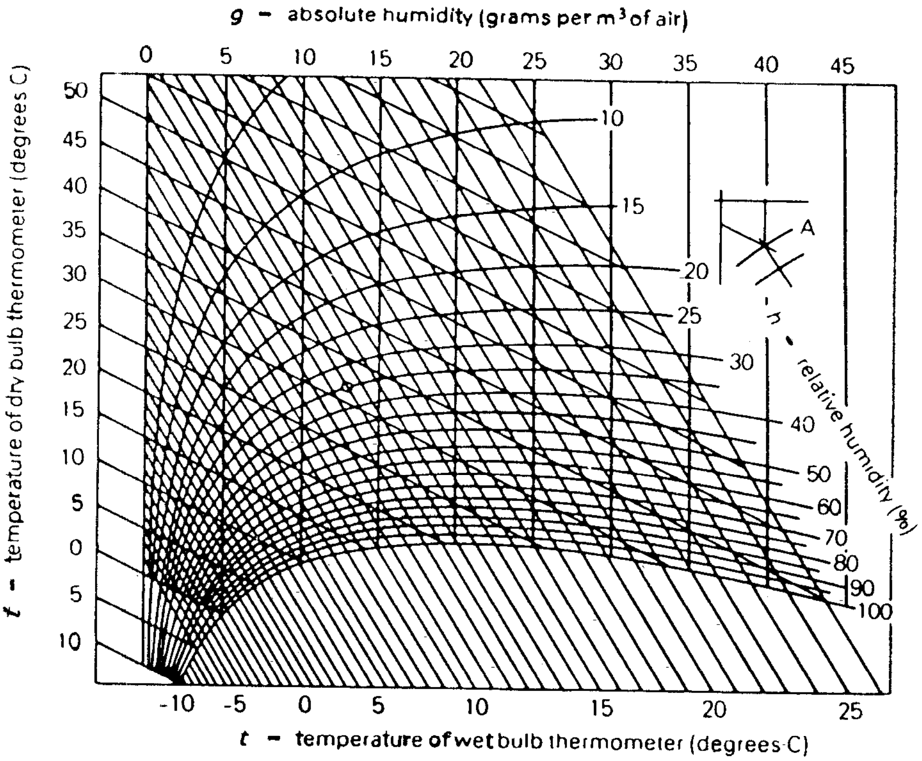


FIG. 26 RELATIONSHIP OF RELATIVE HUMIDITY (h) AND TEMPERATURE (t in °C)

(*Continued from second cover*)

The brushes are used in electric machines operating on dc, ac or ac/dc, systems. The brush technology in the country is sufficiently developed and the brush manufacturers found the existing standard IS 3003 (in parts) lacking in clearly specifying the requirements of brush material and individual brushes fabricated out of blocks. In the new approach, it is decided to prepare the following standards out of existing 4 parts of IS 3003:

a) Definitions and nomenclature of carbon brushes, brush-holders commutators and slip-rings for electrical machinery [Doc : ETD 15 (3100)] [Superseding IS 3003 (Part 1) : 1977],

b) Brush material for electrical machinery [Doc : ETD 15 (3101)] [Superseding IS 3003 (Part 2) : 1977]; and

c) Brushes for electrical machines [Doc : ETD 15 (3102)] [Superseding IS 3003 (Parts 3 & 4) : 1978].

The aim of this standard is to provide uniformly the procedure for tests and the tolerances applicable on the declared values for the brush materials. It has been found difficult to specify definite values of characteristics of brush materials at present as these are brittle, porous and their properties varying much more than the same in the metals.

Samples used for these shall be representative of the lot of material involved and shall be selected by using a recognized or agreed sampling procedure. In view of this, it has not been found possible to give classification of tests for type tests, acceptance tests and criteria for acceptance of any lot of brush material offered for inspection.

The tests for thermal conducting, abrasiveness in carbon brush material were not specified due to insufficient information available at national or international level. The brush manufacturer may be consulted for specific requirements on this subject.

In the preparation of this standard assistance has been derived from:

a) IEC Pub 413 : 1972 'Test procedures for determining physical properties of brush materials for electrical machines', issued by the International Electrotechnical Commission (IEC).

b) IEC Pub 773 : 1983 'Test methods and apparatus for the measurements of the operational characteristics of brushes', issued by the International Eletrotechnical Commission (IEC).

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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